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DOE FUNDAMENTALS HANDBOOK

MECHANICAL SCIENCE

Volume 2 of 2

U.S. Department of Energy **FSC-6910**
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ABSTRACT

The *Mechanical Science* Handbook was developed to assist nuclear facility operating contractors in providing operators, maintenance personnel, and the technical staff with the necessary fundamentals training to ensure a basic understanding of mechanical components and mechanical science. The handbook includes information on diesel engines, heat exchangers, pumps, valves, and miscellaneous mechanical components. This information will provide personnel with a foundation for understanding the construction and operation of mechanical components that are associated with various DOE nuclear facility operations and maintenance.

Key Words: Training Material, Diesel Engine, Heat Exchangers, Pumps, Valves

FOREWORD

The *Department of Energy (DOE) Fundamentals Handbooks* consist of ten academic subjects, which include Mathematics; Classical Physics; Thermodynamics, Heat Transfer, and Fluid Flow; Instrumentation and Control; Electrical Science; Material Science; Mechanical Science; Chemistry; Engineering Symbology, Prints, and Drawings; and Nuclear Physics and Reactor Theory. The handbooks are provided as an aid to DOE nuclear facility contractors.

These handbooks were first published as Reactor Operator Fundamentals Manuals in 1985 for use by DOE category A reactors. The subject areas, subject matter content, and level of detail of the Reactor Operator Fundamentals Manuals were determined from several sources. DOE Category A reactor training managers determined which materials should be included, and served as a primary reference in the initial development phase. Training guidelines from the commercial nuclear power industry, results of job and task analyses, and independent input from contractors and operations-oriented personnel were all considered and included to some degree in developing the text material and learning objectives.

The *DOE Fundamentals Handbooks* represent the needs of various DOE nuclear facilities' fundamental training requirements. To increase their applicability to nonreactor nuclear facilities, the Reactor Operator Fundamentals Manual learning objectives were distributed to the Nuclear Facility Training Coordination Program Steering Committee for review and comment. To update their reactor-specific content, DOE Category A reactor training managers also reviewed and commented on the content. On the basis of feedback from these sources, information that applied to two or more DOE nuclear facilities was considered generic and was included. The final draft of each of the handbooks was then reviewed by these two groups. This approach has resulted in revised modular handbooks that contain sufficient detail such that each facility may adjust the content to fit their specific needs.

Each handbook contains an abstract, a foreword, an overview, learning objectives, and text material, and is divided into modules so that content and order may be modified by individual DOE contractors to suit their specific training needs. Each handbook is supported by a separate examination bank with an answer key.

The *DOE Fundamentals Handbooks* have been prepared for the Assistant Secretary for Nuclear Energy, Office of Nuclear Safety Policy and Standards, by the DOE Training Coordination Program. This program is managed by EG&G Idaho, Inc.

OVERVIEW

The *Department of Energy Fundamentals Handbook* entitled *Mechanical Science* was prepared as an information resource for personnel who are responsible for the operation of the Department's nuclear facilities. Almost all processes that take place in the nuclear facilities involve the use of mechanical equipment and components. A basic understanding of mechanical science is necessary for DOE nuclear facility operators, maintenance personnel, and the technical staff to safely operate and maintain the facility and facility support systems. The information in the handbook is presented to provide a foundation for applying engineering concepts to the job. This knowledge will help personnel more fully understand the impact that their actions may have on the safe and reliable operation of facility components and systems.

The *Mechanical Science* handbook consists of five modules that are contained in two volumes. The following is a brief description of the information presented in each module of the handbook.

Volume 1 of 2

Module 1 - Diesel Engine Fundamentals

Provides information covering the basic operating principles of 2-cycle and 4-cycle diesel engines. Includes operation of engine governors, fuel ejectors, and typical engine protective features.

Module 2 - Heat Exchangers

Describes the construction of plate heat exchangers and tube and shell heat exchangers. Describes the flow patterns and temperature profiles in parallel flow, counter flow, and cross flow heat exchangers.

Module 3 - Pumps

Explains the operation of centrifugal and positive displacement pumps. Topics include net positive suction head, cavitation, gas binding, and pump characteristic curves.

OVERVIEW (Cont.)

Volume 2 of 2

Module 4 - Valves

Introduces the functions of the basic parts common to most types of valves. Provides information on applications of many types of valves. Types of valves covered include gate valves, globe valves, ball valves, plug valves, diaphragm valves, reducing valves, pinch valves, butterfly valves, needle valves, check valves, and safety/relief valves.

Module 5 - Miscellaneous Mechanical Components

Provides information on significant mechanical devices that have widespread application in nuclear facilities but do not fit into the categories of components covered by the other modules. These include cooling towers, air compressors, demineralizers, filters, strainers, etc.

The information contained in this handbook is not all encompassing. An attempt to present the entire subject of mechanical science would be impractical. However, the *Mechanical Science* handbook presents enough information to provide the reader with the fundamental knowledge necessary to understand the advanced theoretical concepts presented in other subject areas, and to understand basic system and equipment operation.

Department of Energy
Fundamentals Handbook

MECHANICAL SCIENCE
Module 4
Valves

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TERMINAL OBJECTIVE

1.0 Without references, **DESCRIBE** the construction and operation of a given type of valve, valve component, or valve actuator, as presented in this module.

ENABLING OBJECTIVES

1.1 **DESCRIBE** the four basic types of flow control elements employed in valve design.

1.2 **DESCRIBE** how valve stem leakage is controlled.

1.3 Given a drawing of a valve, **IDENTIFY** the following:

a. Body
b. Bonnet
c. Stem
d. Actuator
e. Packing
f. Seat
g. Disk

1.4 Given a drawing of a valve, **IDENTIFY** each of the following types of valves:

a. Globe
b. Gate
c. Plug
d. Ball
e. Needle
f. Butterfly
g. Diaphragm
h. Pinch
i. Check
j. Stop check
k. Safety/relief
l. Reducing

1.5 **DESCRIBE** the application of the following types of valves:

a. Globe
b. Gate
c. Plug
d. Ball
e. Needle
f. Butterfly
g. Diaphragm
h. Pinch
i. Check
j. Safety/relief
k. Reducing

1.6 **DESCRIBE** the construction and principle of operation for the following types of valve actuators:

a. Manual
b. Electric motor
c. Pneumatic
d. Hydraulic
e. Solenoid

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VALVE FUNCTIONS AND BASIC PARTS

Valves are the most common single piece of equipment found in DOE facilities. Although there are many types, shapes, and sizes of valves, they all have the same basic parts. This chapter will review the common parts and functions of a valve.

EO 1.1 DESCRIBE the four basic types of flow control elements employed in valve design.

EO 1.2 DESCRIBE how valve stem leakage is controlled.

EO 1.3 Given a drawing of a valve, IDENTIFY the following:

a. Body
b. Bonnet
c. Stem
d. Actuator
e. Packing
f. Seat
g. Disk

Introduction

A valve is a mechanical device that controls the flow of fluid and pressure within a system or process. A valve controls system or process fluid flow and pressure by performing any of the following functions:

- Stopping and starting fluid flow
- Varying (throttling) the amount of fluid flow
- Controlling the direction of fluid flow
- Regulating downstream system or process pressure
- Relieving component or piping over pressure

There are many valve designs and types that satisfy one or more of the functions identified above. A multitude of valve types and designs safely accommodate a wide variety of industrial applications.

Regardless of type, all valves have the following basic parts: the body, bonnet, trim (internal elements), actuator, and packing. The basic parts of a valve are illustrated in Figure 1.

Valve Body

The *body*, sometimes called the shell, is the primary pressure boundary of a valve. It serves as the principal element of a valve assembly because it is the framework that holds everything together.

The body, the first pressure boundary of a valve, resists fluid pressure loads from connecting piping. It receives inlet and outlet piping through threaded, bolted, or welded joints.

Valve bodies are cast or forged into a variety of shapes. Although a sphere or a cylinder would theoretically be the most economical shape to resist fluid pressure when a valve is open, there are many other considerations. For example, many valves require a partition across the valve body to support the seat opening, which is the throttling orifice. With the valve closed, loading on the body is difficult to determine. The valve end connections also distort loads on a simple sphere and more complicated shapes. Ease of manufacture, assembly, and costs are additional important considerations. Hence, the basic form of a valve body typically is not spherical, but ranges from simple block shapes to highly complex shapes in which the bonnet, a removable piece to make assembly possible, forms part of the pressure-resisting body.

Narrowing of the fluid passage (venturi effect) is also a common method for reducing the overall size and cost of a valve. In other instances, large ends are added to the valve for connection into a larger line.

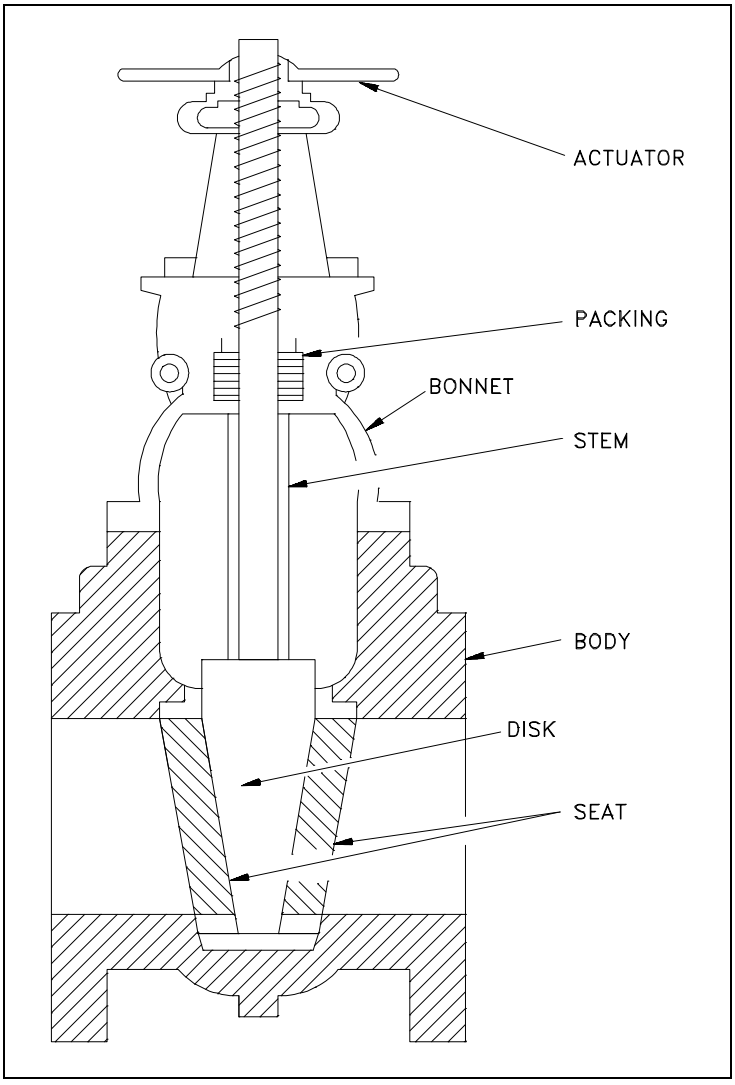

Figure 1 Basic Parts of a Valve

Valve Bonnet

The cover for the opening in the valve body is the *bonnet*. In some designs, the body itself is split into two sections that bolt together. Like valve bodies, bonnets vary in design. Some bonnets function simply as valve covers, while others support valve internals and accessories such as the stem, disk, and actuator.

The bonnet is the second principal pressure boundary of a valve. It is cast or forged of the same material as the body and is connected to the body by a threaded, bolted, or welded joint. In all cases, the attachment of the bonnet to the body is considered a pressure boundary. This means that the weld joint or bolts that connect the bonnet to the body are pressure-retaining parts.

Valve bonnets, although a necessity for most valves, represent a cause for concern. Bonnets can complicate the manufacture of valves, increase valve size, represent a significant cost portion of valve cost, and are a source for potential leakage.

Valve Trim

The internal elements of a valve are collectively referred to as a valve's *trim*. The trim typically includes a *disk, seat, stem,* and *sleeves* needed to guide the stem. A valve's performance is determined by the disk and seat interface and the relation of the disk position to the seat.

Because of the trim, basic motions and flow control are possible. In rotational motion trim designs, the disk slides closely past the seat to produce a change in flow opening. In linear motion trim designs, the disk lifts perpendicularly away from the seat so that an annular orifice appears.

Disk and Seat

For a valve having a bonnet, the disk is the third primary principal pressure boundary. The disk provides the capability for permitting and prohibiting fluid flow. With the disk closed, full system pressure is applied across the disk if the outlet side is depressurized. For this reason, the disk is a pressure-retaining part. Disks are typically forged and, in some designs, hard-surfaced to provide good wear characteristics. A fine surface finish of the seating area of a disk is necessary for good sealing when the valve is closed. Most valves are named, in part, according to the design of their disks.

The seat or seal rings provide the seating surface for the disk. In some designs, the body is machined to serve as the seating surface and seal rings are not used. In other designs, forged seal rings are threaded or welded to the body to provide the seating surface. To improve the wear-resistance of the seal rings, the surface is often hard-faced by welding and then machining the contact surface of the seal ring. A fine surface finish of the seating area is necessary for good sealing when the valve is closed. Seal rings are not usually considered pressure boundary parts because the body has sufficient wall thickness to withstand design pressure without relying upon the thickness of the seal rings.

Stem

The *stem*, which connects the actuator and disk, is responsible for positioning the disk. Stems are typically forged and connected to the disk by threaded or welded joints. For valve designs requiring stem packing or sealing to prevent leakage, a fine surface finish of the stem in the area of the seal is necessary. Typically, a stem is not considered a pressure boundary part.

Connection of the disk to the stem can allow some rocking or rotation to ease the positioning of the disk on the seat. Alternately, the stem may be flexible enough to let the disk position itself against the seat. However, constant fluttering or rotation of a flexible or loosely connected disk can destroy the disk or its connection to the stem.

Two types of valve stems are rising stems and nonrising stems. Illustrated in Figures 2 and 3, these two types of stems are easily distinguished by observation. For a rising stem valve, the stem will rise above the actuator as the valve is opened. This occurs because the stem is threaded and mated with the bushing threads of a yoke that is an integral part of, or is mounted to, the bonnet.

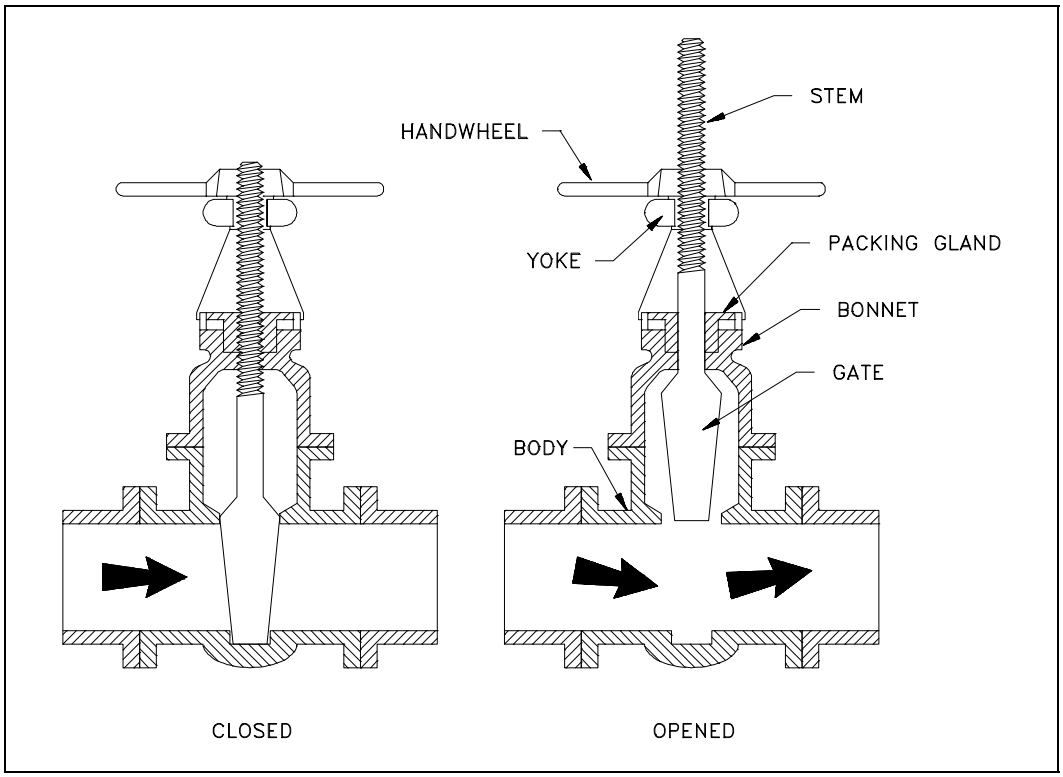

Figure 2 Rising Stems

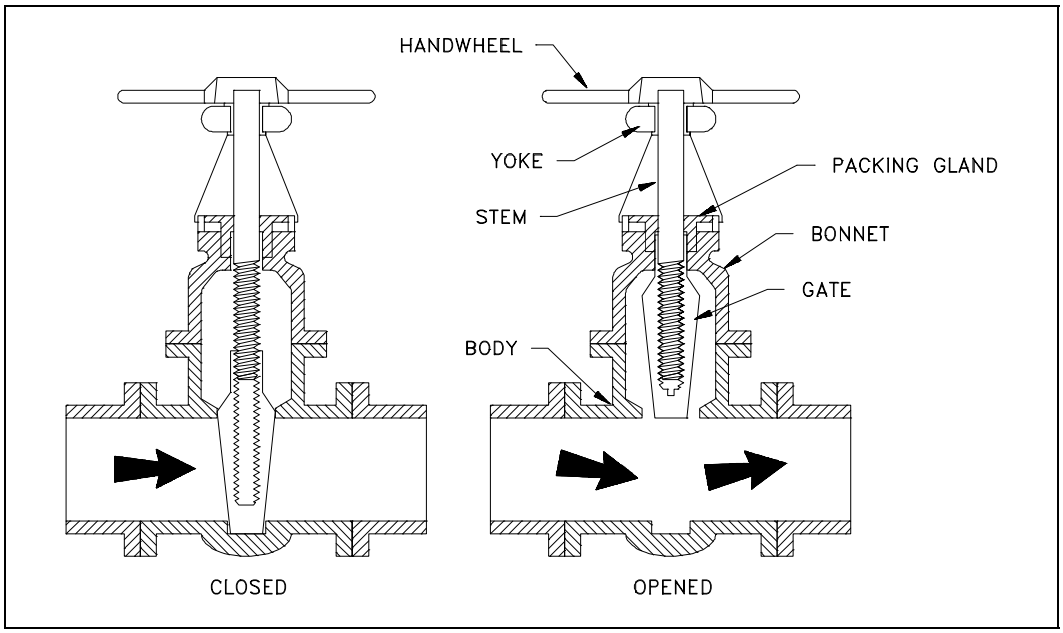

Figure 3 Nonrising Stems

There is no upward stem movement from outside the valve for a nonrising stem design. For the nonrising stem design, the valve disk is threaded internally and mates with the stem threads.

Valve Actuator

The *actuator* operates the stem and disk assembly. An actuator may be a manually operated handwheel, manual lever, motor operator, solenoid operator, pneumatic operator, or hydraulic ram. In some designs, the actuator is supported by the bonnet. In other designs, a yoke mounted to the bonnet supports the actuator.

Except for certain hydraulically controlled valves, actuators are outside of the pressure boundary. Yokes, when used, are always outside of the pressure boundary.

Valve Packing

Most valves use some form of packing to prevent leakage from the space between the stem and the bonnet. *Packing* is commonly a fibrous material (such as flax) or another compound (such as teflon) that forms a seal between the internal parts of a valve and the outside where the stem extends through the body.

Valve packing must be properly compressed to prevent fluid loss and damage to the valve's stem. If a valve's packing is too loose, the valve will leak, which is a safety hazard. If the packing is too tight, it will impair the movement and possibly damage the stem.

Introduction to the Types of Valves

Because of the diversity of the types of systems, fluids, and environments in which valves must operate, a vast array of valve types have been developed. Examples of the common types are the globe valve, gate valve, ball valve, plug valve, butterfly valve, diaphragm valve, check valve, pinch valve, and safety valve. Each type of valve has been designed to meet specific needs. Some valves are capable of throttling flow, other valve types can only stop flow, others work well in corrosive systems, and others handle high pressure fluids. Each valve type has certain inherent advantages and disadvantages. Understanding these differences and how they effect the valve's application or operation is necessary for the successful operation of a facility.

Although all valves have the same basic components and function to control flow in some fashion, the method of controlling the flow can vary dramatically. In general, there are four methods of controlling flow through a valve.

1. Move a disc, or plug into or against an orifice (for example, globe or needle type valve).

2. Slide a flat, cylindrical, or spherical surface across an orifice (for example, gate and plug valves).

3. Rotate a disc or ellipse about a shaft extending across the diameter of an orifice (for example, a butterfly or ball valve).

4. Move a flexible material into the flow passage (for example, diaphragm and pinch valves).

Each method of controlling flow has characteristics that makes it the best choice for a given application of function.

Summary

The following important information in this chapter is summarized below:

Valve Functions and Basic Parts Summary

- There are four basic types of flow control elements employed in valve design.
  1. Move a disc, or plug into or against an orifice (for example, globe or needle type valve).
  2. Slide a flat, cylindrical, or spherical surface across an orifice (for example, gate and plug valves).
  3. Rotate a disc or ellipse about a shaft extending across the diameter of an orifice (for example, a butterfly or ball valve).
  4. Move a flexible material into the flow passage (for example, diaphragm and pinch valves).
- Valve stem leakage is usually controlled by properly compressing the packing around the valve stem.
- There are seven basic parts common to most valves.

TYPES OF VALVES

Due to the various environments, system fluids, and system conditions in which flow must be controlled, a large number of valve designs have been developed. A basic understanding of the differences between the various types of valves, and how these differences affect valve function, will help ensure the proper application of each valve type during design and the proper use of each valve type during operation.

EO 1.4 Given a drawing of a valve, IDENTIFY each of the following types of valves:

a.	**Globe**	**g.**	**Diaphragm**
b.	**Gate**	**h.**	**Pinch**
c.	**Plug**	**i.**	**Check**
d.	**Ball**	**j.**	**Safety/relief**
e.	**Needle**	**k.**	**Reducing**
f.	**Butterfly**		

EO 1.5 DESCRIBE the application of the following types of valves:

a.	**Globe**	**g.**	**Diaphragm**
b.	**Gate**	**h.**	**Pinch**
c.	**Plug**	**i.**	**Check**
d.	**Ball**	**j.**	**Safety/relief**
e.	**Needle**	**k.**	**Reducing**
f.	**Butterfly**		

Gate Valves

A *gate* valve is a linear motion valve used to start or stop fluid flow; however, it does not regulate or throttle flow. The name gate is derived from the appearance of the disk in the flow stream. Figure 4 illustrates a gate valve.

The disk of a gate valve is completely removed from the flow stream when the valve is fully open. This characteristic offers virtually no resistance to flow when the valve is open. Hence, there is little pressure drop across an open gate valve.

When the valve is fully closed, a disk-to-seal ring contact surface exists for 360°, and good sealing is provided. With the proper mating of a disk to the seal ring, very little or no leakage occurs across the disk when the gate valve is closed.

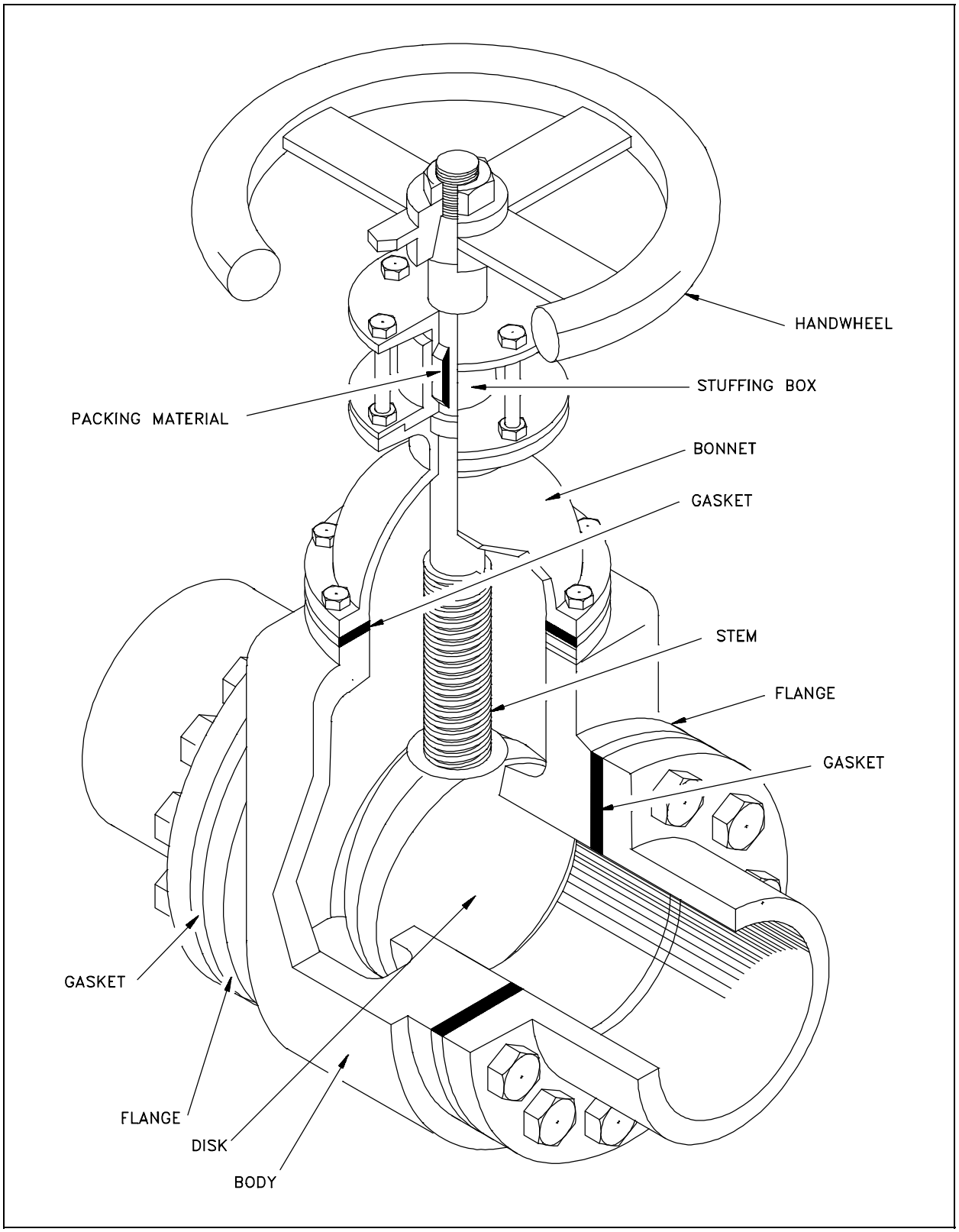

Figure 4 Gate Valve

On opening the gate valve, the flow path is enlarged in a highly nonlinear manner with respect to percent of opening. This means that flow rate does not change evenly with stem travel. Also, a partially open gate disk tends to vibrate from the fluid flow. Most of the flow change occurs near shutoff with a relatively high fluid velocity causing disk and seat wear and eventual leakage if used to regulate flow. For these reasons, gate valves are not used to regulate or throttle flow.

A gate valve can be used for a wide variety of fluids and provides a tight seal when closed. The major disadvantages to the use of a gate valve are:

- It is not suitable for throttling applications.
- It is prone to vibration in the partially open state.
- It is more subject to seat and disk wear than a globe valve.
- Repairs, such as lapping and grinding, are generally more difficult to accomplish.

Gate Valve Disk Design

Gate valves are available with a variety of disks. Classification of gate valves is usually made by the type disk used: solid wedge, flexible wedge, split wedge, or parallel disk.

Solid wedges, flexible wedges, and split wedges are used in valves having inclined seats. Parallel disks are used in valves having parallel seats.

Regardless of the style of wedge or disk used, the disk is usually replaceable. In services where solids or high velocity may cause rapid erosion of the seat or disk, these components should have a high surface hardness and should have replacement seats as well as disks. If the seats are not replaceable, seat damage requires removal of the valve from the line for refacing of the seat, or refacing of the seat in place. Valves being used in corrosion service should normally be specified with replaceable seats.

Solid Wedge

The solid wedge gate valve shown in Figure 5 is the most commonly used disk because of its simplicity and strength. A valve with this type of wedge may be installed in any position and it is suitable for almost all fluids. It is practical for turbulent flow.

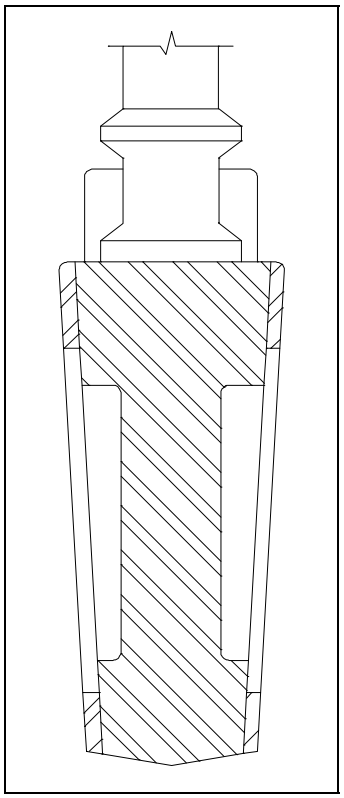

Figure 5
Solid Wedge Gate Valve

Flexible Wedge

The flexible wedge gate valve illustrated in Figure 6 is a one-piece disk with a cut around the perimeter to improve the ability to match error or change in the angle between the seats. The cut varies in size, shape, and depth. A shallow, narrow cut gives little flexibility but retains strength. A deeper and wider cut, or cast-in recess, leaves little material at the center, which allows more flexibility but compromises strength.

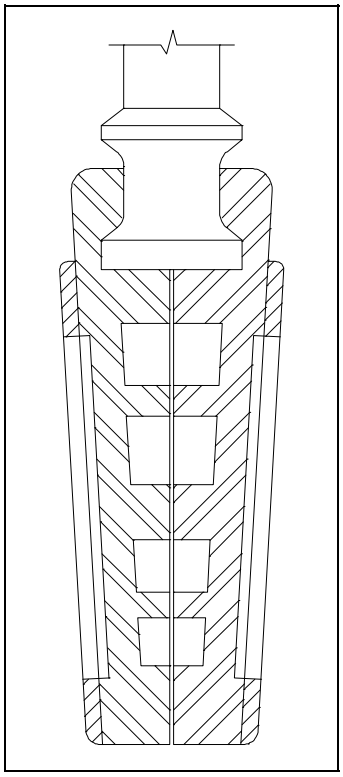

Figure 6
Flexible Wedge Gate Valve

A correct profile of the disk half in the flexible wedge design can give uniform deflection properties at the disk edge, so that the wedging force applied in seating will force the disk seating surface uniformly and tightly against the seat.

Gate valves used in steam systems have flexible wedges. The reason for using a flexible gate is to prevent binding of the gate within the valve when the valve is in the closed position. When steam lines are heated, they expand and cause some distortion of valve bodies. If a solid gate fits snugly between the seat of a valve in a cold steam system, when the system is heated and pipes elongate, the seats will compress against the gate and clamp the valve shut. This problem is overcome by using a flexible gate, whose design allows the gate to flex as the valve seat compresses it.

The major problem associated with flexible gates is that water tends to collect in the body neck. Under certain conditions, the admission of steam may cause the valve body neck to rupture, the bonnet to lift off, or the seat ring to collapse. Following correct warming procedures prevent these problems.

Split Wedge

Split wedge gate valves, as shown in Figure 7, are of the ball and socket design. These are self-adjusting and self-aligning to both seating surfaces. The disk is free to adjust itself to the seating surface if one-half of the disk is slightly out of alignment because of foreign matter lodged between the disk half and the seat ring. This type of wedge is suitable for handling noncondensing gases and liquids at normal temperatures, particularly corrosive liquids. Freedom of movement of the disk in the carrier prevents binding even though the valve may have been closed when hot and later contracted due to cooling. This type of valve should be installed with the stem in the vertical position.

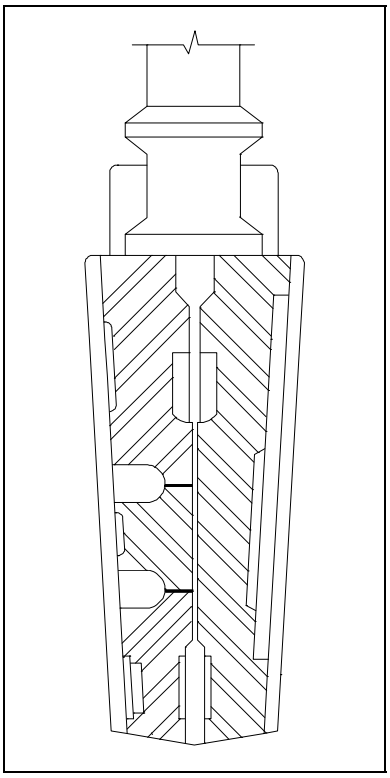

Figure 7 Split Wedge Gate Valve

Parallel Disk

The parallel disk gate valve illustrated in Figure 8 is designed to prevent valve binding due to thermal transients. This design is used in both low and high pressure applications.

The wedge surfaces between the parallel face disk halves are caused to press together under stem thrust and spread apart the disks to seal against the seats. The tapered wedges may be part of the disk halves or they may be separate elements. The lower wedge may bottom out on a rib at the valve bottom so that the stem can develop seating force. In one version, the wedge contact surfaces are curved to keep the point of contact close to the optimum.

In other parallel disk gates, the two halves do not move apart under wedge action. Instead, the upstream pressure holds the downstream disk against the seat. A carrier ring lifts the disks, and a spring or springs hold the disks apart and seated when there is no upstream pressure.

Another parallel gate disk design provides for sealing only one port. In these designs, the high pressure side pushes the disk open (relieving the disk) on the high pressure side, but forces the disk closed on the low pressure side. With such designs, the amount of seat leakage tends to decrease as differential pressure across the seat increases. These valves will usually have a flow direction marking which will show which side is the high pressure (relieving) side. Care should be taken to ensure that these valves are not installed backwards in the system.

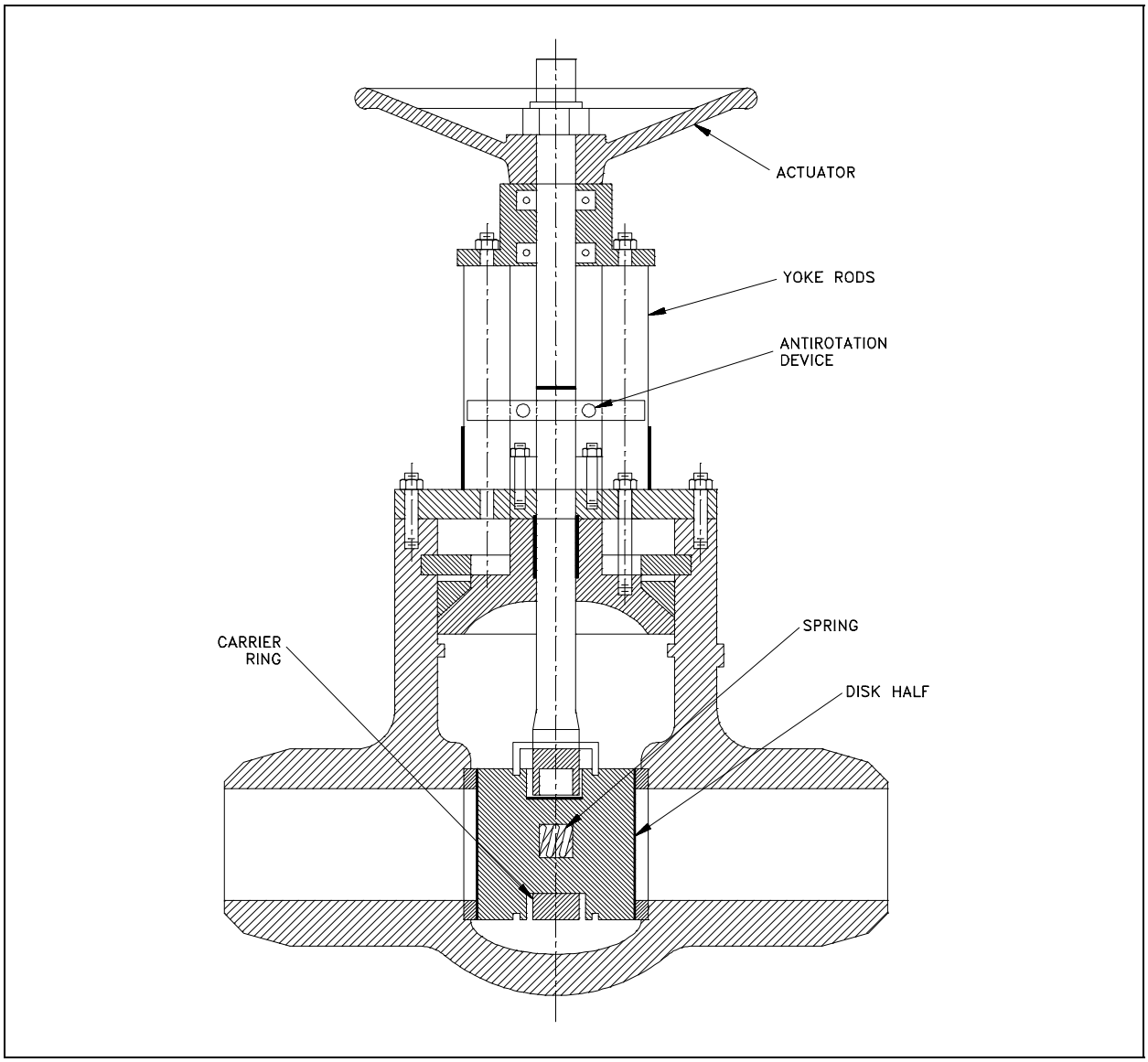

Figure 8 Parallel Disk Gate Valve

Some parallel disk gate valves used in high pressure systems are made with an integral bonnet vent and bypass line. A three-way valve is used to position the line to bypass in order to equalize pressure across the disks prior to opening. When the gate valve is closed, the three-way valve is positioned to vent the bonnet to one side or the other. This prevents moisture from accumulating in the bonnet. The three-way valve is positioned to the high pressure side of the gate valve when closed to ensure that flow does not bypass the isolation valve. The high pressure acts against spring compression and forces one gate off of its seat. The three-way valve vents this flow back to the pressure source.

Gate Valve Stem Design

Gate valves are classified as either rising stem or nonrising stem valves. For the nonrising stem gate valve, the stem is threaded on the lower end into the gate. As the hand wheel on the stem is rotated, the gate travels up or down the stem on the threads while the stem remains vertically stationary. This type valve will almost always have a pointer-type indicator threaded onto the upper end of the stem to indicate valve position. Figures 2 and 3 illustrate rising-stem gate valves and nonrising stem gate valves.

The nonrising stem configuration places the stem threads within the boundary established by the valve packing out of contact with the environment. This configuration assures that the stem merely rotates in the packing without much danger of carrying dirt into the packing from outside to inside.

Rising stem gate valves are designed so that the stem is raised out of the flowpath when the valve is open. Rising stem gate valves come in two basic designs. Some have a stem that rises through the handwheel while others have a stem that is threaded to the bonnet.

Gate Valve Seat Design

Seats for gate valves are either provided integral with the valve body or in a seat ring type of construction. Seat ring construction provides seats which are either threaded into position or are pressed into position and seal welded to the valve body. The latter form of construction is recommended for higher temperature service.

Integral seats provide a seat of the same material of construction as the valve body while the pressed-in or threaded-in seats permit variation. Rings with hard facings may be supplied for the application where they are required.

Small, forged steel, gate valves may have hard faced seats pressed into the body. In some series, this type of valve in sizes from 1/2 to 2 inches is rated for 2500 psig steam service. In large gate valves, disks are often of the solid wedge type with seat rings threaded in, welded in, or pressed in. Screwed in seat rings are considered replaceable since they may be removed and new seat rings installed.

Globe Valves

A globe valve is a linear motion valve used to stop, start, and regulate fluid flow. A Z-body globe valve is illustrated in Figure 9.

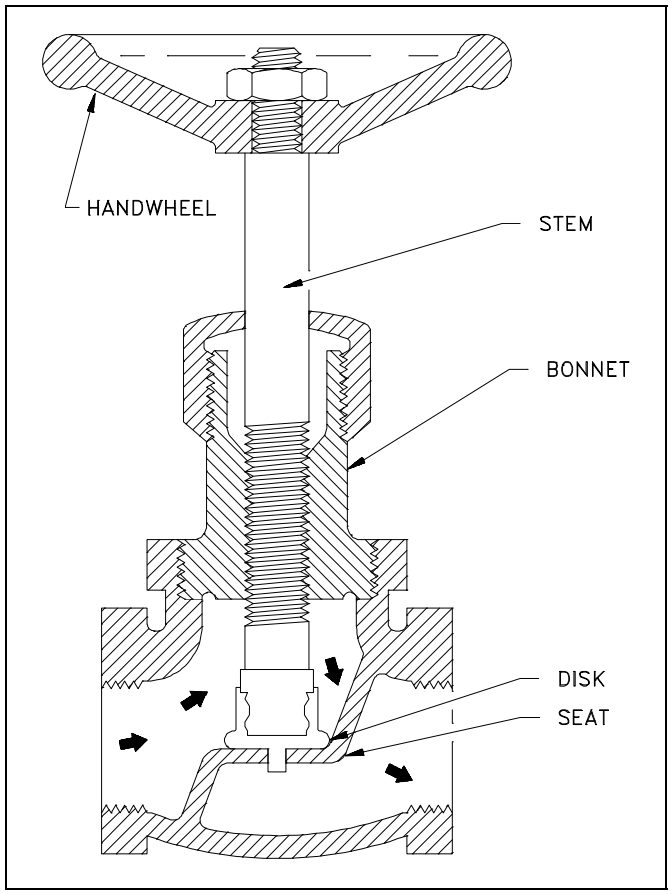

Figure 9 Z-Body Globe Valve

As shown in Figure 9, the globe valve disk can be totally removed from the flowpath or it can completely close the flowpath. The essential principle of globe valve operation is the perpendicular movement of the disk away from the seat. This causes the annular space between the disk and seat ring to gradually close as the valve is closed. This characteristic gives the globe valve good throttling ability, which permits its use in regulating flow. Therefore, the globe valve may be used for both stopping and starting fluid flow and for regulating flow.

When compared to a gate valve, a globe valve generally yields much less seat leakage. This is because the disk-to-seat ring contact is more at right angles, which permits the force of closing to tightly seat the disk.

Globe valves can be arranged so that the disk closes against or in the same direction of fluid flow. When the disk closes against the direction of flow, the kinetic energy of the fluid impedes closing but aids opening of the valve. When the disk closes in the same direction of flow, the kinetic energy of the fluid aids closing but impedes opening. This characteristic is preferable to other designs when quick-acting stop valves are necessary.

Globe valves also have drawbacks. The most evident shortcoming of the simple globe valve is the high head loss from two or more right angle turns of flowing fluid. Obstructions and discontinuities in the flowpath lead to head loss. In a large high pressure line, the fluid dynamic effects from pulsations, impacts, and pressure drops can damage trim, stem packing, and actuators. In addition, large valve sizes require considerable power to operate and are especially noisy in high pressure applications.

Other drawbacks of globe valves are the large openings necessary for disk assembly, heavier weight than other valves of the same flow rating, and the cantilevered mounting of the disk to the stem.

Globe Valve Body Designs

The three primary body designs for globe valves are Z-body, Y-body, and Angle.

Z-Body Design

The simplest design and most common for water applications is the Z-body. The Z-body is illustrated in Figure 9. For this body design, the Z-shaped diaphragm or partition across the globular body contains the seat. The horizontal setting of the seat allows the stem and disk to travel at right angles to the pipe axis. The stem passes through the bonnet which is attached to a large opening at the top of the valve body. This provides a symmetrical form that simplifies manufacture, installation, and repair.

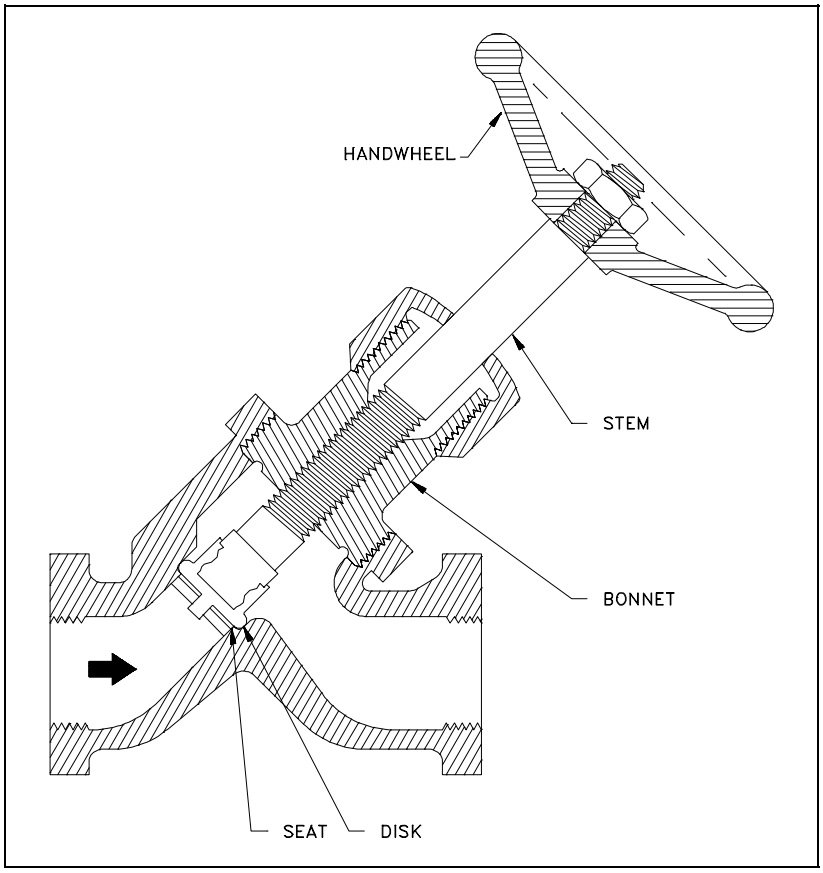

Figure 10 Y-Body Globe Valve

Y-Body Design

Figure 10 illustrates a typical Y-body globe valve. This design is a remedy for the high pressure drop inherent in globe valves. The seat and stem are angled at approximately 45°. The angle yields a straighter flowpath (at full opening) and provides the stem, bonnet, and packing a relatively pressure-resistant envelope.

Y-body globe valves are best suited for high pressure and other severe services. In small sizes for intermittent flows, the pressure loss may not be as important as the other considerations favoring the Y-body design. Hence, the flow passage of small Y-body globe valves is not as carefully streamlined as that for larger valves.

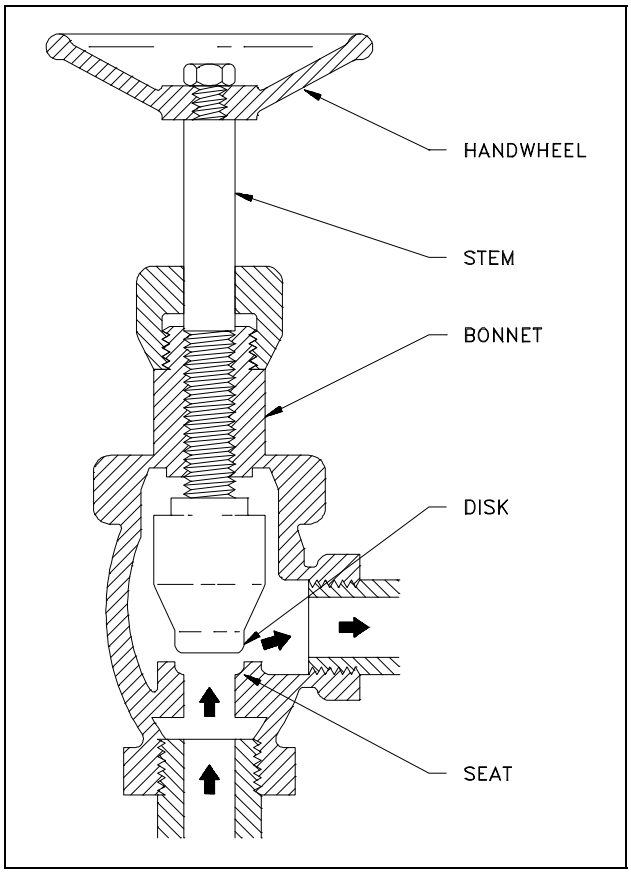

Figure 11 Angle Globe Valve

Angle Valve Design

The angle body globe valve design, illustrated in Figure 11, is a simple modification of the basic globe valve. Having ends at right angles, the diaphragm can be a simple flat plate. Fluid is able to flow through with only a single 90° turn and discharge downward more symmetrically than the discharge from an ordinary globe. A particular advantage of the angle body design is that it can function as both a valve and a piping elbow.

For moderate conditions of pressure, temperature, and flow, the angle valve closely resembles the ordinary globe. The angle valve's discharge conditions are favorable with respect to fluid dynamics and erosion.

Globe Valve Disks

Most globe valves use one of three basic disk designs: the ball disk, the composition disk, and the plug disk.

Ball Disk

The ball disk fits on a tapered, flat-surfaced seat. The ball disk design is used primarily in relatively low pressure and low temperature systems. It is capable of throttling flow, but is primarily used to stop and start flow.

Composition Disk

The composition disk design uses a hard, nonmetallic insert ring on the disk. The insert ring creates a tighter closure. Composition disks are primarily used in steam and hot water applications. They resist erosion and are sufficiently resilient to close on solid particles without damaging the valve. Composition disks are replaceable.

Plug Disk

Because of its configuration, the plug disk provides better throttling than ball or composition designs. Plug disks are available in a variety of specific configurations. In general, they are all long and tapered.

Globe Valve Disk and Stem Connections

Globe valves employ two methods for connecting disk and stem: T-slot construction and disk nut construction. In the T-slot design, the disk slips over the stem. In the disk nut design, the disk is screwed into the stem.

Globe Valve Seats

Globe valve seats are either integral with or screwed into the valve body. Many globe valves have backseats. A backseat is a seating arrangement that provides a seal between the stem and bonnet. When the valve is fully open, the disk seats against the backseat. The backseat design prevents system pressure from building against the valve packing.

Globe Valve Direction of Flow

For low temperature applications, globe and angle valves are ordinarily installed so that pressure is under the disk. This promotes easy operation, helps protect the packing, and eliminates a certain amount of erosive action to the seat and disk faces. For high temperature steam service, globe valves are installed so that pressure is above the disk. Otherwise, the stem will contract upon cooling and tend to lift the disk off the seat.

Ball Valves

A ball valve is a rotational motion valve that uses a ball-shaped disk to stop or start fluid flow. The ball, shown in Figure 12, performs the same function as the disk in the globe valve. When the valve handle is turned to open the valve, the ball rotates to a point where the hole through the ball is in line with the valve body inlet and outlet. When the valve is shut, the ball is rotated so that the hole is perpendicular to the flow openings of the valve body and the flow is stopped.

Most ball valve actuators are of the quick-acting type, which require a 90° turn of the valve handle to operate the valve. Other ball valve actuators are planetary gear-operated. This type of gearing allows the use of a relatively small handwheel and operating force to operate a fairly large valve.

Some ball valves have been developed with a spherical surface coated plug that is off to one side in the open position and rotates into the flow passage until it blocks the flowpath completely. Seating is accomplished by the eccentric movement of the plug. The valve requires no lubrication and can be used for throttling service.

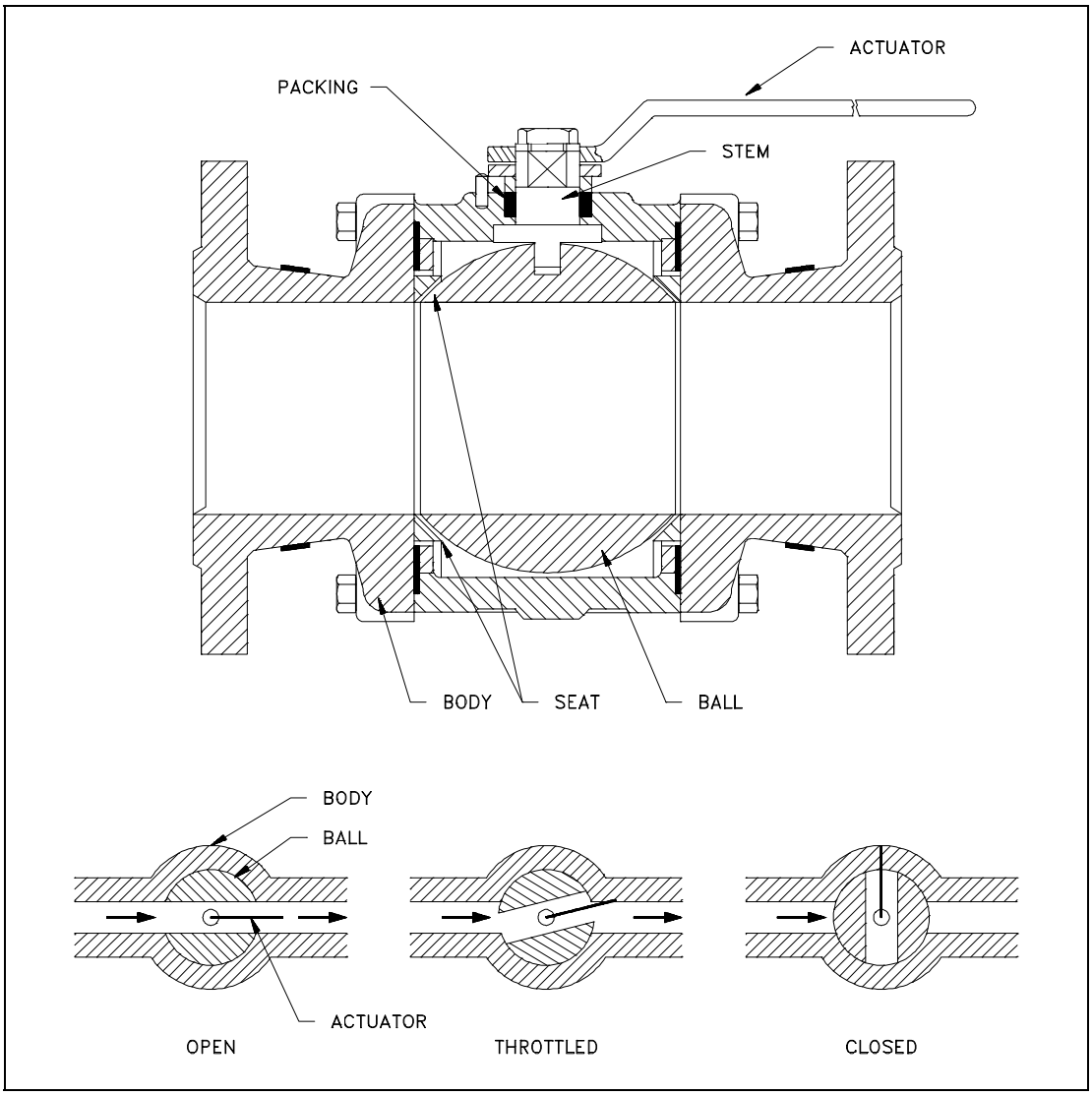

Figure 12 Typical Ball Valve

Advantages

A ball valve is generally the least expensive of any valve configuration and has low maintenance costs. In addition to quick, quarter turn on-off operation, ball valves are compact, require no lubrication, and give tight sealing with low torque.

Disadvantages

Conventional ball valves have relatively poor throttling characteristics. In a throttling position, the partially exposed seat rapidly erodes because of the impingement of high velocity flow.

Port Patterns

Ball valves are available in the venturi, reduced, and full port pattern. The full port pattern has a ball with a bore equal to the inside diameter of the pipe.

Valve Materials

Balls are usually metallic in metallic bodies with trim (seats) produced from elastomeric (elastic materials resembling rubber) materials. Plastic construction is also available.

The resilient seats for ball valves are made from various elastomeric material. The most common seat materials are teflon (TFE), filled TFE, Nylon, Buna-N, Neoprene, and combinations of these materials. Because of the elastomeric materials, these valves cannot be used at elevated temperatures. Care must be used in the selection of the seat material to ensure that it is compatible with the materials being handled by the valve.

Ball Valve Stem Design

The stem in a ball valve is not fastened to the ball. It normally has a rectangular portion at the ball end which fits into a slot cut into the ball. The enlargement permits rotation of the ball as the stem is turned.

Ball Valve Bonnet Design

A bonnet cap fastens to the body, which holds the stem assembly and ball in place. Adjustment of the bonnet cap permits compression of the packing, which supplies the stem seal. Packing for ball valve stems is usually in the configuration of die-formed packing rings normally of TFE, TFE-filled, or TFE-impregnated material. Some ball valve stems are sealed by means of O-rings rather than packing.

Ball Valve Position

Some ball valves are equipped with stops that permit only 90° rotation. Others do not have stops and may be rotated 360°. With or without stops, a 90° rotation is all that is required for closing or opening a ball valve.

The handle indicates valve ball position. When the handle lies along the axis of the valve, the valve is open. When the handle lies 90° across the axis of the valve, the valve is closed. Some ball valve stems have a groove cut in the top face of the stem that shows the flowpath through the ball. Observation of the groove position indicates the position of the port through the ball. This feature is particularly advantageous on multiport ball valves.

Plug Valves

A plug valve is a rotational motion valve used to stop or start fluid flow. The name is derived from the shape of the disk, which resembles a plug. A plug valve is shown in Figure 13. The simplest form of a plug valve is the petcock. The body of a plug valve is machined to receive the tapered or cylindrical plug. The disk is a solid plug with a bored passage at a right angle to the longitudinal axis of the plug.

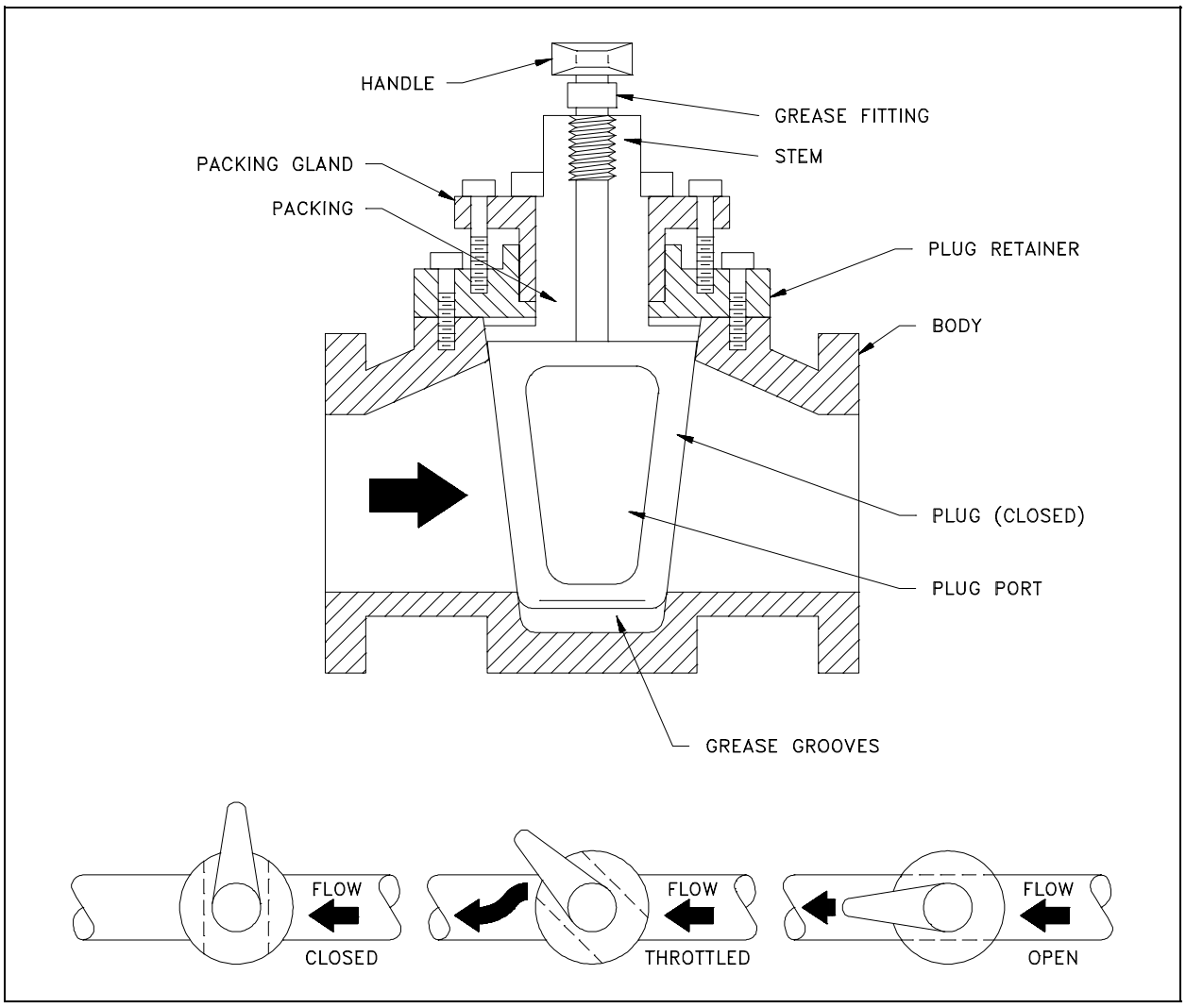

Figure 13 Plug Valve

In the open position, the passage in the plug lines up with the inlet and outlet ports of the valve body. When the plug is turned 90° from the open position, the solid part of the plug blocks the ports and stops fluid flow.

Plug valves are available in either a lubricated or nonlubricated design and with a variety of styles of port openings through the plug as well as a number of plug designs.

Plug Ports

An important characteristic of the plug valve is its easy adaptation to multiport construction. Multiport valves are widely used. Their installation simplifies piping, and they provide a more convenient operation than multiple gate valves. They also eliminate pipe fittings. The use of a multiport valve, depending upon the number of ports in the plug valve, eliminates the need of as many as four conventional shutoff valves.

Plug valves are normally used in non-throttling, on-off operations, particularly where frequent operation of the valve is necessary. These valves are not normally recommended for throttling service because, like the gate valve, a high percentage of flow change occurs near shutoff at high velocity. However, a diamond-shaped port has been developed for throttling service.

Multiport Plug Valves

Multiport valves are particularly advantageous on transfer lines and for diverting services. A single multiport valve may be installed in lieu of three or four gate valves or other types of shutoff valve. A disadvantage is that many multiport valve configurations do not completely shut off flow.

In most cases, one flowpath is always open. These valves are intended to divert the flow of one line while shutting off flow from the other lines. If complete shutoff of flow is a requirement, it is necessary that a style of multiport valve be used that permits this, or a secondary valve should be installed on the main line ahead of the multiport valve to permit complete shutoff of flow.

In some multiport configurations, simultaneous flow to more than one port is also possible. Great care should be taken in specifying the particular port arrangement required to guarantee that proper operation will be possible.

Plug Valve Disks

Plugs are either round or cylindrical with a taper. They may have various types of port openings, each with a varying degree of area relative to the corresponding inside diameter of the pipe.

Rectangular Port Plug

The most common port shape is the rectangular port. The rectangular port represents at least 70% of the corresponding pipe's cross-sectional area.

Round Port Plug

Round port plug is a term that describes a valve that has a round opening through the plug. If the port is the same size or larger than the pipe's inside diameter, it is referred to as a full port. If the opening is smaller than the pipe's inside diameter, the port is referred to as a standard round port. Valves having standard round ports are used only where restriction of flow is unimportant.

Diamond Port Plug

A diamond port plug has a diamond-shaped port through the plug. This design is for throttling service. All diamond port valves are venturi restricted flow type.

Lubricated Plug Valve Design

Clearances and leakage prevention are the chief considerations in plug valves. Many plug valves are of all metal construction. In these versions, the narrow gap around the plug can allow leakage. If the gap is reduced by sinking the taper plug deeper into the body, actuation torque climbs rapidly and galling can occur. To remedy this condition, a series of grooves around the body and plug port openings is supplied with grease prior to actuation. Applying grease lubricates the plug motion and seals the gap between plug and body. Grease injected into a fitting at the top of the stem travels down through a check valve in the passageway, past the plug top to the grooves on the plug, and down to a well below the plug. The lubricant must be compatible with the temperature and nature of the fluid. All manufacturers of lubricated plug valves have developed a series of lubricants that are compatible with a wide range of media. Their recommendation should be followed as to which lubricant is best suited for the service.

The most common fluids controlled by plug valves are gases and liquid hydrocarbons. Some water lines have these valves, provided that lubricant contamination is not a serious danger. Lubricated plug valves may be as large as 24 inches and have pressure capabilities up to 6000 psig. Steel or iron bodies are available. The plug can be cylindrical or tapered.

Nonlubricated Plugs

There are two basic types of nonlubricated plug valves: lift-type and elastomer sleeve or plug coated. Lift-type valves provide a means of mechanically lifting the tapered plug slightly to disengage it from the seating surface to permit easy rotation. The mechanical lifting can be accomplished with a cam or external lever.

In a common, nonlubricated, plug valve having an elastomer sleeve, a sleeve of TFE completely surrounds the plug. It is retained and locked in place by a metal body. This design results in a primary seal being maintained between the sleeve and the plug at all times regardless of position. The TFE sleeve is durable and inert to all but a few rarely encountered chemicals. It also has a low coefficient of friction and is, therefore, self-lubricating.

Manually Operated Plug Valve Installation

When installing plug valves, care should be taken to allow room for the operation of the handle, lever, or wrench. The manual operator is usually longer than the valve, and it rotates to a position parallel to the pipe from a position 90° to the pipe.

Plug Valve Glands

The gland of the plug valve is equivalent to the bonnet of a gate or globe valve. The gland secures the stem assembly to the valve body. There are three general types of glands: single gland, screwed gland, and bolted gland.

To ensure a tight valve, the plug must be seated at all times. Gland adjustment should be kept tight enough to prevent the plug from becoming unseated and exposing the seating surfaces to the live fluid. Care should be exercised to not overtighten the gland, which will result in a metal-to-metal contact between the body and the plug. Such a metal-to-metal contact creates an additional force which will require extreme effort to operate the valve.

Diaphragm Valves

A diaphragm valve is a linear motion valve that is used to start, regulate, and stop fluid flow. The name is derived from its flexible disk, which mates with a seat located in the open area at the top of the valve body to form a seal. A diaphragm valve is illustrated in Figure 14.

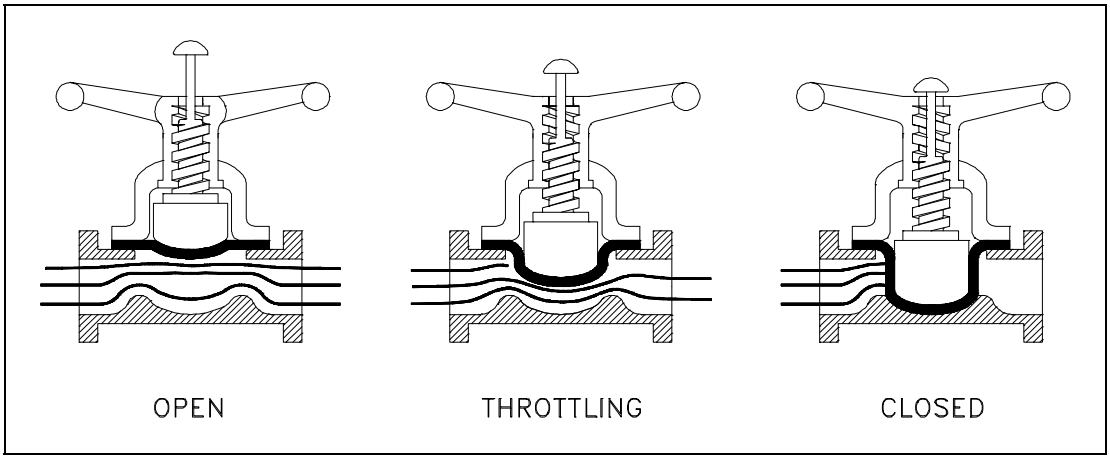

Figure 14 Straight Through Diaphragm Valve

Diaphragm valves are, in effect, simple "pinch clamp" valves. A resilient, flexible diaphragm is connected to a compressor by a stud molded into the diaphragm. The compressor is moved up and down by the valve stem. Hence, the diaphragm lifts when the compressor is raised. As the compressor is lowered, the diaphragm is pressed against the contoured bottom in the straight through valve illustrated in Figure 14 or the body weir in the weir-type valve illustrated in Figure 15.

Diaphragm valves can also be used for throttling service. The weir-type is the better throttling valve but has a limited range. Its throttling characteristics are essentially those of a quick-opening valve because of the large shutoff area along the seat.

A weir-type diaphragm valve is available to control small flows. It uses a two-piece compressor component. Instead of the entire diaphragm lifting off the weir when the valve is opened, the first increments of stem travel raise an inner compressor component that causes only the central part of the diaphragm to lift. This creates a relatively small opening through the center of the valve. After the inner compressor is completely open, the outer compressor component is raised along with the inner compressor and the remainder of the throttling is similar to the throttling that takes place in a conventional valve.

Diaphragm valves are particularly suited for the handling of corrosive fluids, fibrous slurries, radioactive fluids, or other fluids that must remain free from contamination.

Diaphragm Construction

The operating mechanism of a diaphragm valve is not exposed to the media within the pipeline. Sticky or viscous fluids cannot get into the bonnet to interfere with the operating mechanism. Many fluids that would clog, corrode, or gum up the working parts of most other types of valves will pass through a diaphragm valve without causing problems. Conversely, lubricants used for the operating mechanism cannot be allowed to contaminate the fluid being handled. There are no packing glands to maintain and no possibility of stem leakage. There is a wide choice of available diaphragm materials. Diaphragm life depends upon the nature of the material handled, temperature, pressure, and frequency of operation.

Some elastomeric diaphragm materials may be unique in their excellent resistance to certain chemicals at high temperatures. However, the mechanical properties of any elastomeric material will be lowered at the higher temperature with possible destruction of the diaphragm at high pressure. Consequently, the manufacturer should be consulted when they are used in elevated temperature applications.

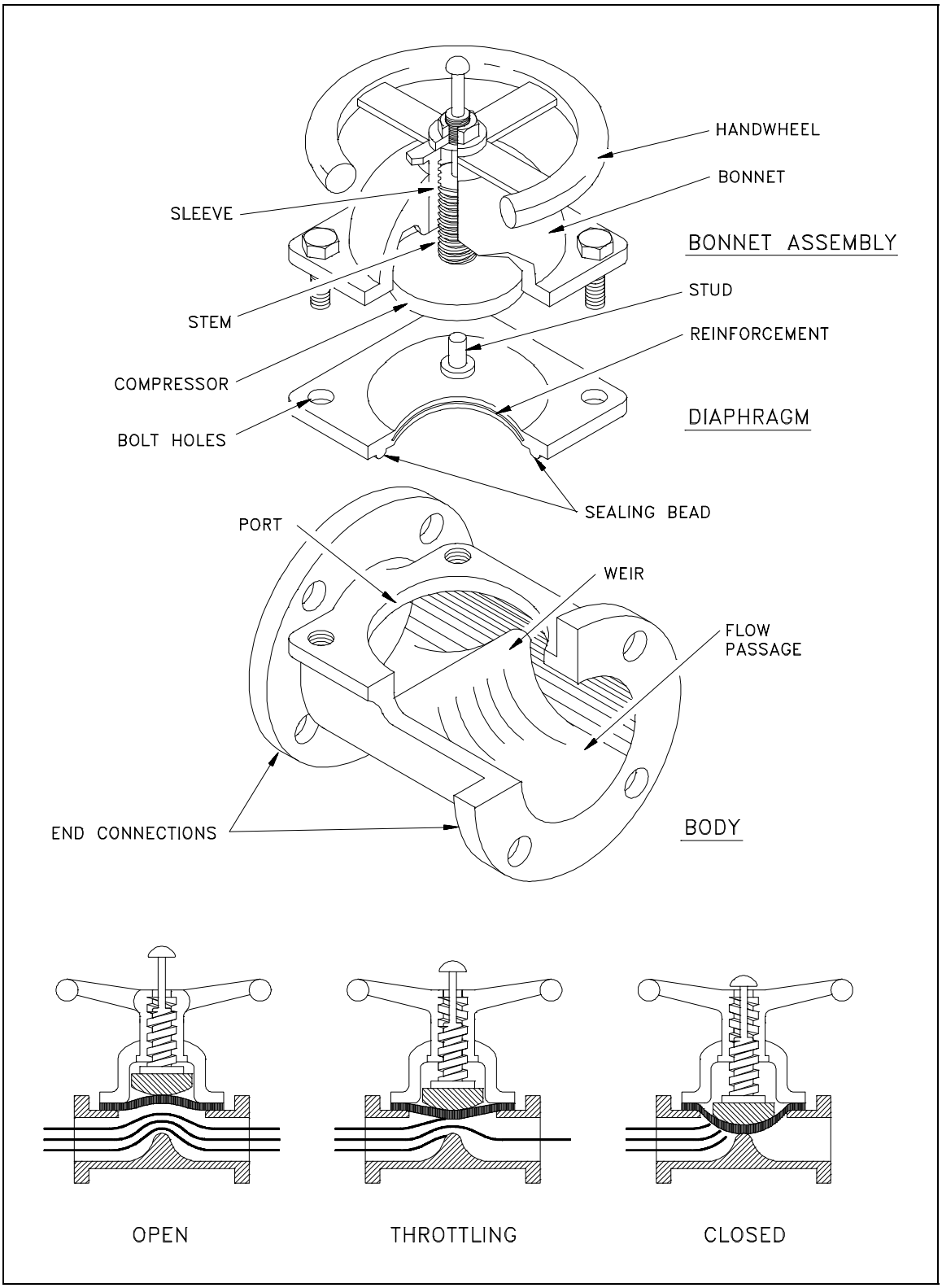

Figure 15 Weir Diaphragm Valve

All elastomeric materials operate best below 150°F. Some will function at higher temperatures. Viton, for example, is noted for its excellent chemical resistance and stability at high temperatures. However, when fabricated into a diaphragm, Viton is subject to lowered tensile strength just as any other elastomeric material would be at elevated temperatures. Fabric bonding strength is also lowered at elevated temperatures, and in the case of Viton, temperatures may be reached where the bond strength could become critical.

Fluid concentrations is also a consideration for diaphragm selection. Many of the diaphragm materials exhibit satisfactory corrosion resistance to certain corrodents up to a specific concentration and/or temperature. The elastomer may also have a maximum temperature limitation based on mechanical properties which could be in excess of the allowable operating temperature depending upon its corrosion resistance. This should be checked from a corrosion table.

Diaphragm Valve Stem Assemblies

Diaphragm valves have stems that do not rotate. The valves are available with indicating and nonindicating stems. The indicating stem valve is identical to the nonindicating stem valve except that a longer stem is provided to extend up through the handwheel. For the nonindicating stem design, the handwheel rotates a stem bushing that engages the stem threads and moves the stem up and down. As the stem moves, so does the compressor that is pinned to the stem. The diaphragm, in turn, is secured to the compressor.

Diaphragm Valve Bonnet Assemblies

Some diaphragm valves use a quick-opening bonnet and lever operator. This bonnet is interchangeable with the standard bonnet on conventional weir-type bodies. A 90° turn of the lever moves the diaphragm from full open to full closed. Diaphragm valves may also be equipped with chain wheel operators, extended stems, bevel gear operators, air operators, and hydraulic operators.

Many diaphragm valves are used in vacuum service. Standard bonnet construction can be employed in vacuum service through 4 inches in size. On valves 4 inches and larger, a sealed, evacuated, bonnet should be employed. This is recommended to guard against premature diaphragm failure.

Sealed bonnets are supplied with a seal bushing on the nonindicating types and a seal bushing plus O-ring on the indicating types. Construction of the bonnet assembly of a diaphragm valve is illustrated in Figure 15. This design is recommended for valves that are handling dangerous liquids and gases. In the event of a diaphragm failure, the hazardous materials will not be released to the atmosphere. If the materials being handled are extremely hazardous, it is recommended that a means be provided to permit a safe disposal of the corrodents from the bonnet.

Reducing Valves

Reducing valves automatically reduce supply pressure to a preselected pressure as long as the supply pressure is at least as high as the selected pressure. As illustrated in Figure 16, the principal parts of the reducing valve are the main valve; an upward-seating valve that has a piston on top of its valve stem, an upward-seating auxiliary (or controlling) valve, a controlling diaphragm, and an adjusting spring and screw.

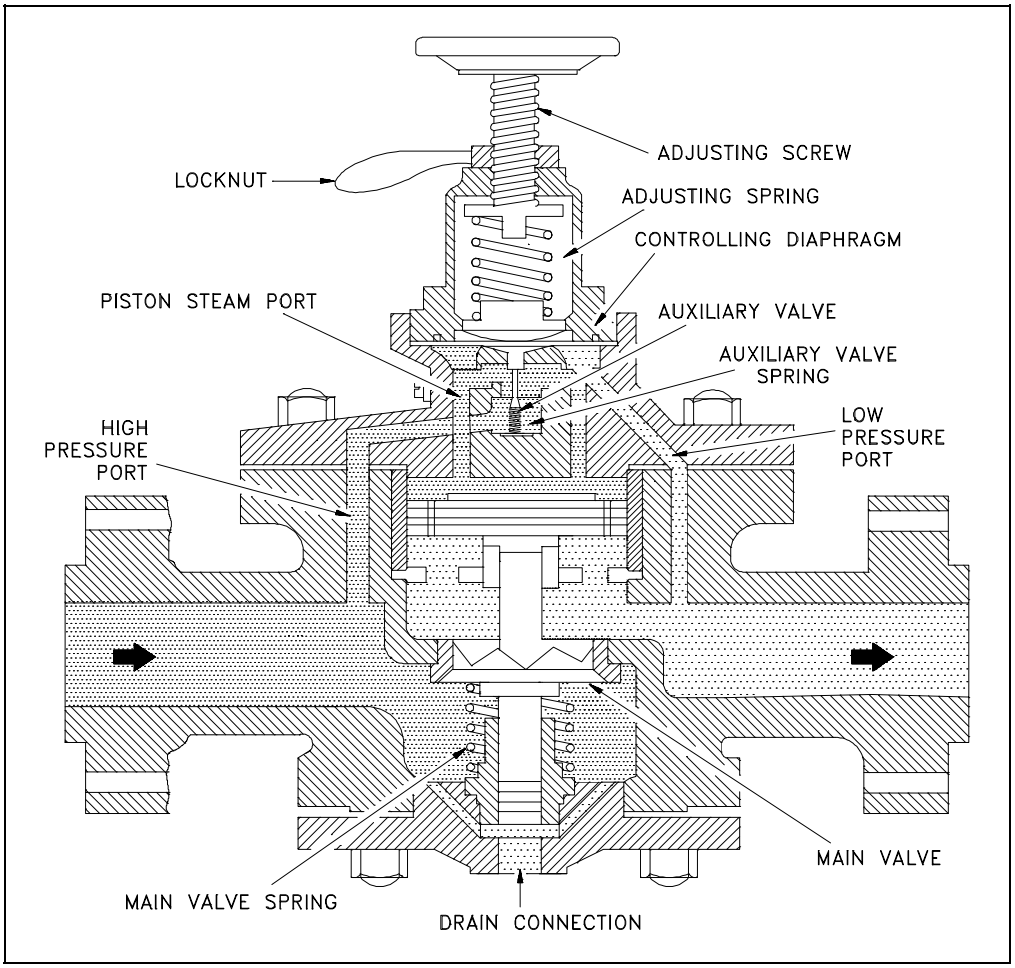

Figure 16 Variable Reducing Valve

Reducing valve operation is controlled by high pressure at the valve inlet and the adjusting screw on top of the valve assembly. The pressure entering the main valve assists the main valve spring in keeping the reducing valve closed by pushing upward on the main valve disk. However, some of the high pressure is bled to an auxiliary valve on top of the main valve. The auxiliary valve controls the admission of high pressure to the piston on top of the main valve. The piston has a larger surface area than the main valve disk, resulting in a net downward force to open the main valve. The auxiliary valve is controlled by a controlling diaphragm located directly over the auxiliary valve.

The controlling diaphragm transmits a downward force that tends to open the auxiliary valve. The downward force is exerted by the adjusting spring, which is controlled by the adjusting screw. Reduced pressure from the main valve outlet is bled back to a chamber beneath the diaphragm to counteract the downward force of the adjusting spring. The position of the auxiliary valve, and ultimately the position of the main valve, is determined by the position of the diaphragm. The position of the diaphragm is determined by the strength of the opposing forces of the downward force of the adjusting spring versus the upward force of the outlet reduced pressure. Other reducing valves work on the same basic principle, but may use gas, pneumatic, or hydraulic controls in place of the adjusting spring and screw.

Non-variable reducing valves, illustrated in Figure 17, replace the adjusting spring and screw with a pre-pressurized dome over the diaphragm. The valve stem is connected either directly or indirectly to the diaphragm. The valve spring below the diaphragm keeps the valve closed. As in the variable valve, reduced pressure is bled through an orifice to beneath the diaphragm to open the valve. Valve position is determined by the strength of the opposing forces of the downward force of the pre-pressurized dome versus the upward force of the outlet-reduced pressure.

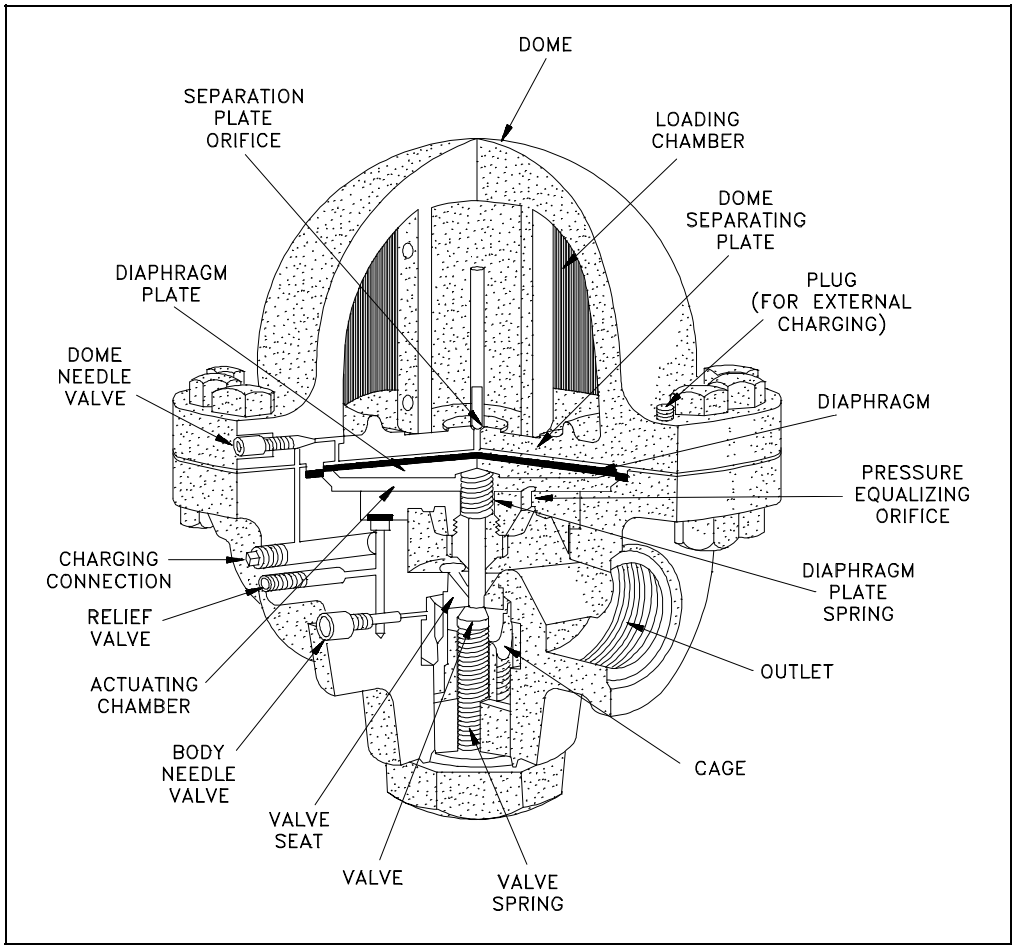

Figure 17 Non-Variable Reducing Valve

Non-variable reducing valves eliminate the need for the intermediate auxiliary valve found in variable reducing valves by having the opposing forces react directly on the diaphragm. Therefore, non-variable reducing valves are more responsive to large pressure variations and are less susceptible to failure than are variable reducing valves.

Pinch Valves

The relatively inexpensive pinch valve, illustrated in Figure 18, is the simplest in any valve design. It is simply an industrial version of the pinch cock used in the laboratory to control the flow of fluids through rubber tubing.

Pinch valves are suitable for on-off and throttling services. However, the effective throttling range is usually between 10% and 95% of the rated flow capacity.

Pinch valves are ideally suited for the handling of slurries, liquids with large amounts of suspended solids, and systems that convey solids pneumatically. Because the operating mechanism is completely isolated from the fluid, these valves also find application where corrosion or metal contamination of the fluid might be a problem.

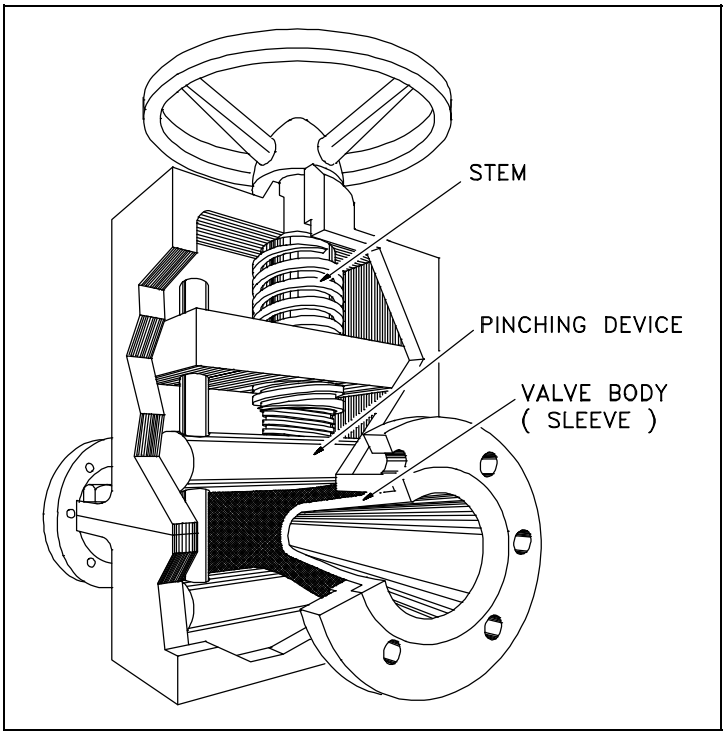

Figure 18 Pinch Valves

The pinch control valve consists of a sleeve molded of rubber or other synthetic material and a pinching mechanism. All of the operating portions are completely external to the valve. The molded sleeve is referred to as the valve body.

Pinch valve bodies are manufactured of natural and synthetic rubbers and plastics which have good abrasion resistance properties. These properties permit little damage to the valve sleeve, thereby providing virtually unimpeded flow. Sleeves are available with either extended hubs and clamps designed to slip over a pipe end, or with a flanged end having standard dimensions.

Pinch Valve Bodies

Pinch valves have molded bodies reinforced with fabric. Pinch valves generally have a maximum operating temperature of 250°F. At 250°F, maximum operating pressure varies generally from 100 psig for a 1-inch diameter valve and decreases to 15 psig for a 12-inch diameter valve. Special pinch valves are available for temperature ranges of -100°F to 550°F and operating pressures of 300 psig.

Most pinch valves are supplied with the sleeve (valve body) exposed. Another style fully encloses the sleeve within a metallic body. This type controls flow either with the conventional wheel and screw pinching device, hydraulically, or pneumatically with the pressure of the liquid or gas within the metal case forcing the sleeve walls together to shut off flow.

Most exposed sleeve valves have limited vacuum application because of the tendency of the sleeves to collapse when vacuum is applied. Some of the encased valves can be used on vacuum service by applying a vacuum within the metal casing and thus preventing the collapse of the sleeve.

Butterfly Valves

A butterfly valve, illustrated in Figure 19, is a rotary motion valve that is used to stop, regulate, and start fluid flow. Butterfly valves are easily and quickly operated because a 90° rotation of the handle moves the disk from a fully closed to fully opened position. Larger butterfly valves are actuated by handwheels connected to the stem through gears that provide mechanical advantage at the expense of speed.

Butterfly valves possess many advantages over gate, globe, plug, and ball valves, especially for large valve applications. Savings in weight, space, and cost are the most obvious advantages. The maintenance costs are usually low because there are a minimal number of moving parts and there are no pockets to trap fluids.

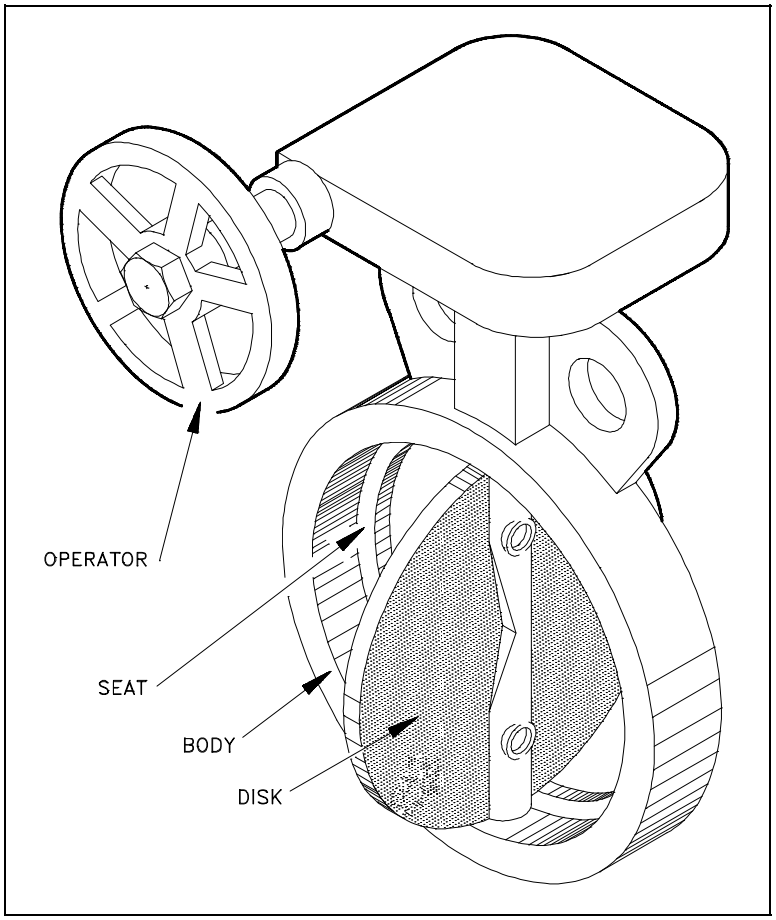

Figure 19 Typical Butterfly Valve

Butterfly valves are especially well-suited for the handling of large flows of liquids or gases at relatively low pressures and for the handling of slurries or liquids with large amounts of suspended solids.

Butterfly valves are built on the principle of a pipe damper. The flow control element is a disk of approximately the same diameter as the inside diameter of the adjoining pipe, which rotates on either a vertical or horizontal axis. When the disk lies parallel to the piping run, the valve is fully opened. When the disk approaches the perpendicular position, the valve is shut. Intermediate positions, for throttling purposes, can be secured in place by handle-locking devices.

Butterfly Valve Seat Construction

Stoppage of flow is accomplished by the valve disk sealing against a seat that is on the inside diameter periphery of the valve body. Many butterfly valves have an elastomeric seat against which the disk seals. Other butterfly valves have a seal ring arrangement that uses a clamp-ring and backing-ring on a serrated edged rubber ring. This design prevents extrusion of the O-rings. In early designs, a metal disk was used to seal against a metal seat. This arrangement did not provide a leak-tight closure, but did provide sufficient closure in some applications (i.e., water distribution lines).

Butterfly Valve Body Construction

Butterfly valve body construction varies. The most economical is the wafer type that fits between two pipeline flanges. Another type, the lug wafer design, is held in place between two pipe flanges by bolts that join the two flanges and pass through holes in the valve's outer casing. Butterfly valves are available with conventional flanged ends for bolting to pipe flanges, and in a threaded end construction.

Butterfly Valve Disk and Stem Assemblies

The stem and disk for a butterfly valve are separate pieces. The disk is bored to receive the stem. Two methods are used to secure the disk to the stem so that the disk rotates as the stem is turned. In the first method, the disk is bored through and secured to the stem with bolts or pins. The alternate method involves boring the disk as before, then shaping the upper stem bore to fit a squared or hex-shaped stem. This method allows the disk to "float" and seek its center in the seat. Uniform sealing is accomplished and external stem fasteners are eliminated. This method of assembly is advantageous in the case of covered disks and in corrosive applications.

In order for the disk to be held in the proper position, the stem must extend beyond the bottom of the disk and fit into a bushing in the bottom of the valve body. One or two similar bushings are along the upper portion of the stem as well. These bushings must be either resistant to the media being handled or sealed so that the corrosive media cannot come into contact with them.

Stem seals are accomplished either with packing in a conventional stuffing box or by means of O-ring seals. Some valve manufacturers, particularly those specializing in the handling of corrosive materials, place a stem seal on the inside of the valve so that no material being handled by the valve can come into contact with the valve stem. If a stuffing box or external O-ring is employed, the fluid passing through the valve will come into contact with the valve stem.

Needle Valves

A needle valve, as shown in Figure 20, is used to make relatively fine adjustments in the amount of fluid flow.

The distinguishing characteristic of a needle valve is the long, tapered, needle-like point on the end of the valve stem. This "needle" acts as a disk. The longer part of the needle is smaller than the orifice in the valve seat and passes through the orifice before the needle seats. This arrangement permits a very gradual increase or decrease in the size of the opening. Needle valves are often used as component parts of other, more complicated valves. For example, they are used in some types of reducing valves.

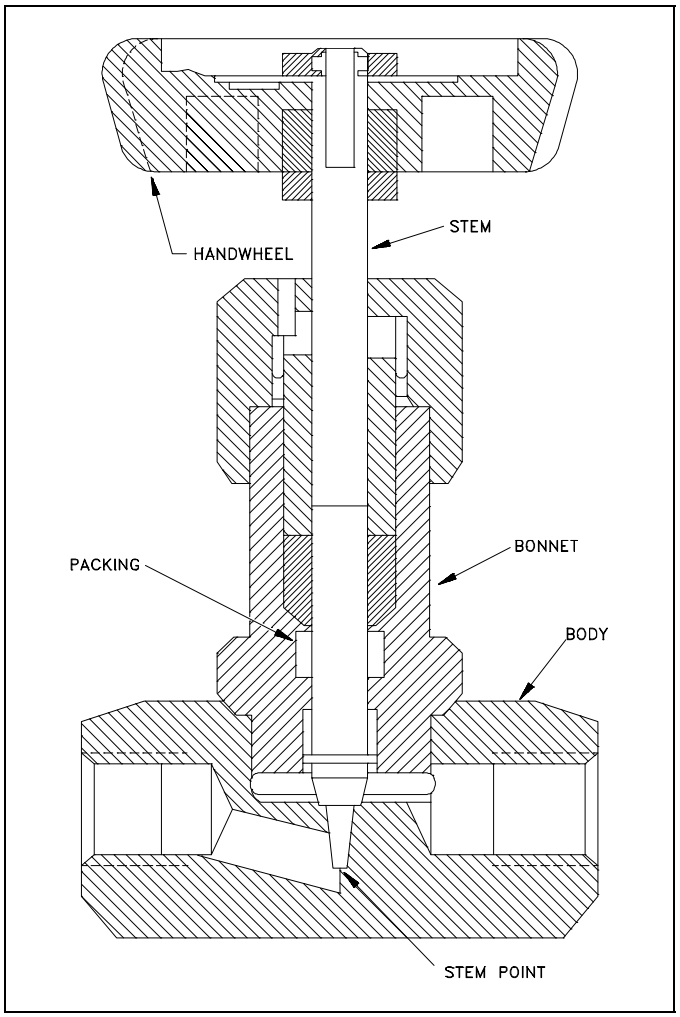

Figure 20 Needle Valve

Needle Valve Applications

Most constant pressure pump governors have needle valves to minimize the effects of fluctuations in pump discharge pressure. Needle valves are also used in some components of automatic combustion control systems where very precise flow regulation is necessary.

Needle Valve Body Designs

One type of body design for a needle valve is the bar stock body. Bar stock bodies are common, and, in globe types, a ball swiveling in the stem provides the necessary rotation for seating without damage. The bar stock body is illustrated in Figure 21.

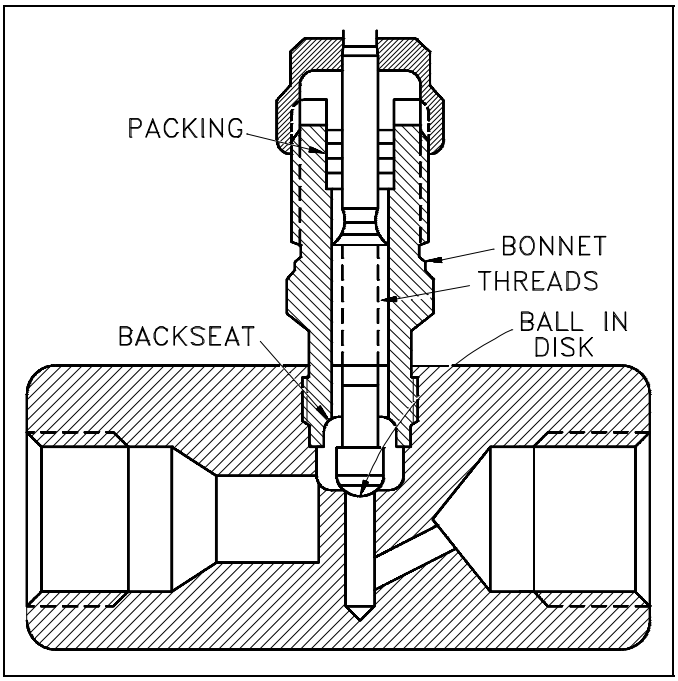

Figure 21 Bar-Stock Instrument Valve

Needle valves are frequently used as metering valves. Metering valves are used for extremely fine flow control. The thin disk or orifice allows for linear flow characteristics. Therefore, the number of handwheel turns can be directly correlated to the amount of flow. A typical metering valve has a stem with 40 threads per inch.

Needle valves generally use one of two styles of stem packing: an O-ring with TFE backing rings or a TFE packing cylinder. Needle valves are often equipped with replaceable seats for ease of maintenance.

Check Valves

Check valves are designed to prevent the reversal of flow in a piping system. These valves are activated by the flowing material in the pipeline. The pressure of the fluid passing through the system opens the valve, while any reversal of flow will close the valve. Closure is accomplished by the weight of the check mechanism, by back pressure, by a spring, or by a combination of these means. The general types of check valves are swing, tilting-disk, piston, butterfly, and stop.

Swing Check Valves

A swing check valve is illustrated in Figure 22. The valve allows full, unobstructed flow and automatically closes as pressure decreases. These valves are fully closed when the flow reaches zero and prevent back flow. Turbulence and pressure drop within the valve are very low.

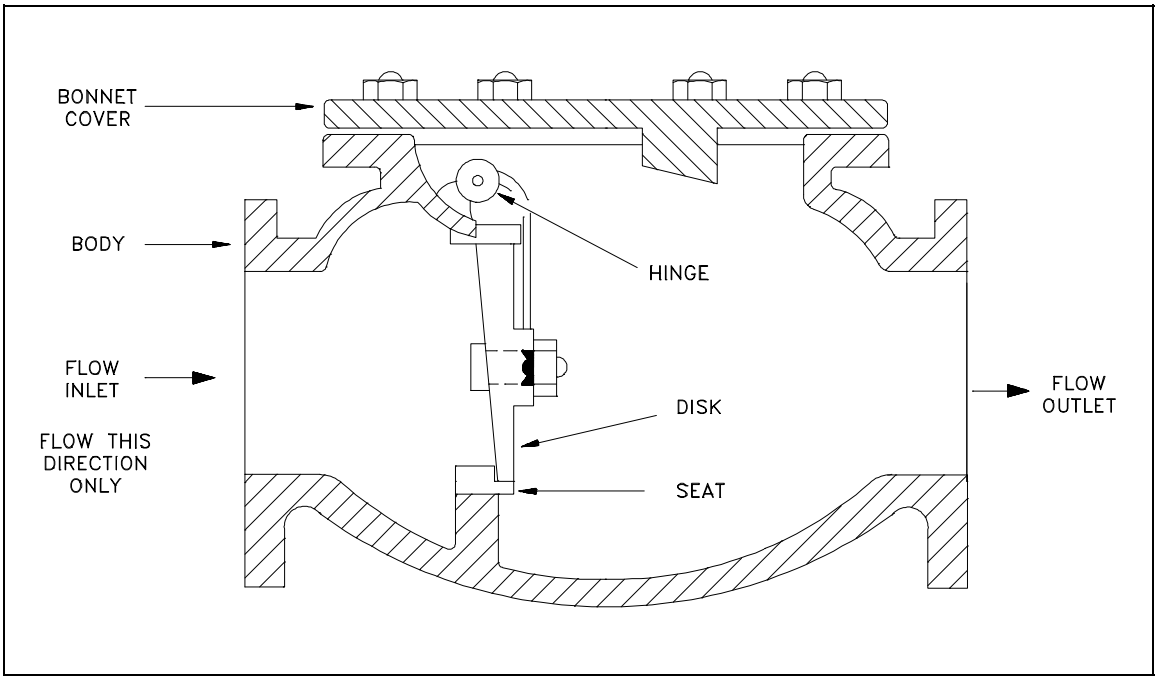

Figure 22 Swing Check Valve

A swing check valve is normally recommended for use in systems employing gate valves because of the low pressure drop across the valve. Swing check valves are available in either Y-pattern or straight body design. A straight check valve is illustrated in Figure 22. In either style, the disk and hinge are suspended from the body by means of a hinge pin. Seating is either metal-to-metal or metal seat to composition disk. Composition disks are usually recommended for services where dirt or other particles may be present in the fluid, where noise is objectionable, or where positive shutoff is required.

Straight body swing check valves contain a disk that is hinged at the top. The disk seals against the seat, which is integral with the body. This type of check valve usually has replaceable seat rings. The seating surface is placed at a slight angle to permit easier opening at lower pressures, more positive sealing, and less shock when closing under higher pressures.

Swing check valves are usually installed in conjunction with gate valves because they provide relatively free flow. They are recommended for lines having low velocity flow and should not be used on lines with pulsating flow when the continual flapping or pounding would be destructive to the seating elements. This condition can be partially corrected by using an external lever and weight.

Tilting Disk Check Valves

The tilting disk check valve, illustrated in Figure 23, is similar to the swing check valve. Like the swing check, the tilting disk type keeps fluid resistance and turbulence low because of its straight-through design.

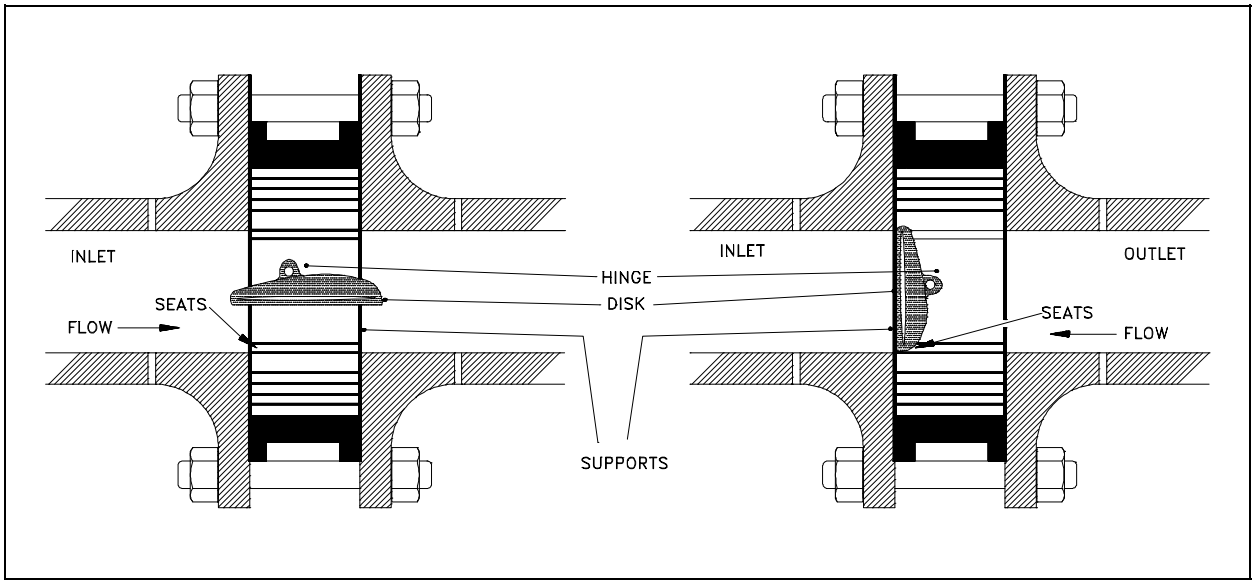

Figure 23 Operation of Tilting Disk Check Valve

Tilting disk check valves can be installed in horizontal lines and vertical lines having upward flow. Some designs simply fit between two flange faces and provide a compact, lightweight installation, particularly in larger diameter valves.

The disk lifts off of the seat to open the valve. The airfoil design of the disk allows it to "float" on the flow. Disk stops built into the body position the disk for optimum flow characteristics. A large body cavity helps minimize flow restriction. As flow decreases, the disk starts closing and seals before reverse flow occurs. Backpressure against the disk moves it across the soft seal into the metal seat for tight shutoff without slamming. If the reverse flow pressure is insufficient to cause a tight seal, the valve may be fitted with an external lever and weight.

These valves are available with a soft seal ring, metal seat seal, or a metal-to-metal seal. The latter is recommended for high temperature operation. The soft seal rings are replaceable, but the valve must be removed from the line to make the replacement.

Lift Check Valves

A lift check valve, illustrated in Figure 24, is commonly used in piping systems in which globe valves are being used as a flow control valve. They have similar seating arrangements as globe valves.

Lift check valves are suitable for installation in horizontal or vertical lines with upward flow. They are recommended for use with steam, air, gas, water, and on vapor lines with high flow velocities. These valves are available in three body patterns: horizontal, angle, and vertical.

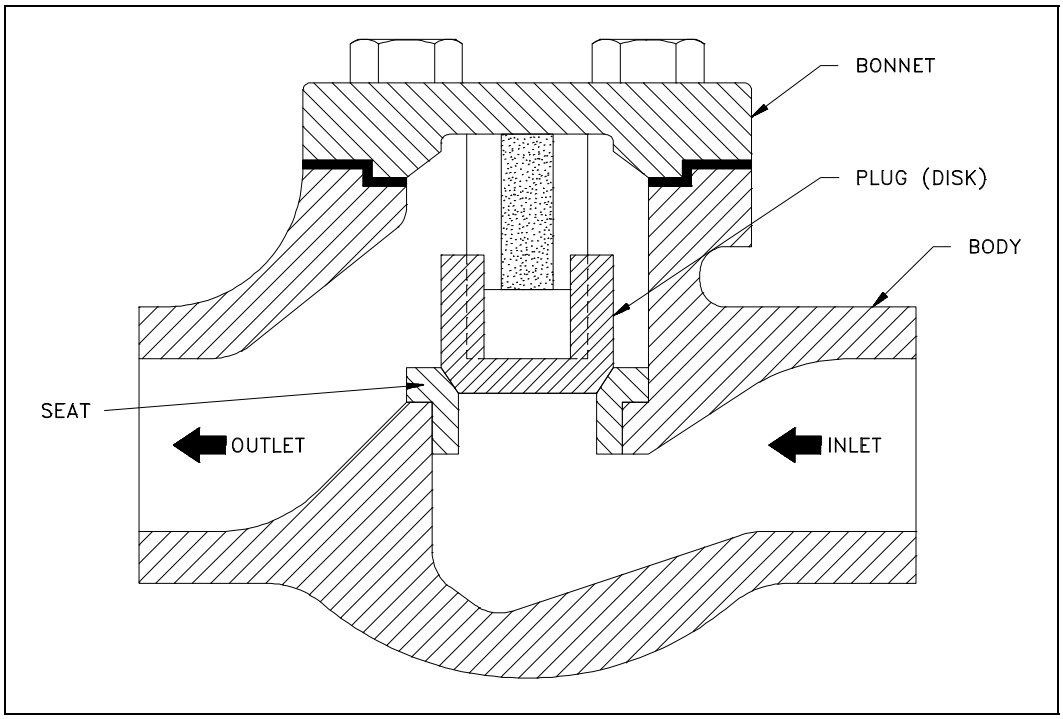

Figure 24 Lift Check Valve

Flow to lift check valves must always enter below the seat. As the flow enters, the disk or ball is raised within guides from the seat by the pressure of the upward flow. When the flow stops or reverses, the disk or ball is forced onto the seat of the valve by both the backflow and gravity.

Some types of lift check valves may be installed horizontally. In this design, the ball is suspended by a system of guide ribs. This type of check valve design is generally employed in plastic check valves.

The seats of metallic body lift check valves are either integral with the body or contain renewable seat rings. Disk construction is similar to the disk construction of globe valves with either metal or composition disks. Metal disk and seat valves can be reground using the same techniques as is used for globe valves.

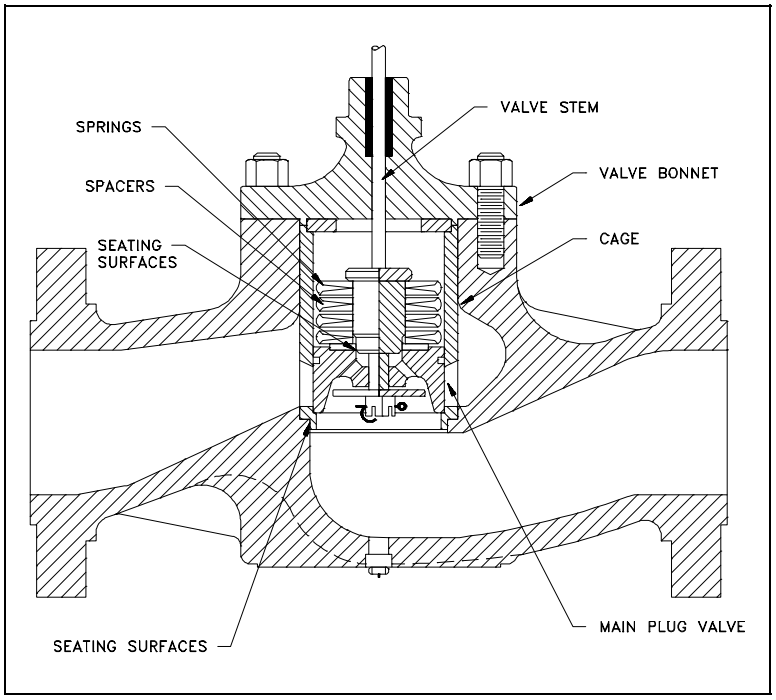

Figure 25 Piston Check Valve

Piston Check Valves

A piston check valve, illustrated in Figure 25, is essentially a lift check valve. It has a dashpot consisting of a piston and cylinder that provides a cushioning effect during operation. Because of the similarity in design to lift check valves, the flow characteristics through a piston check valve are essentially the same as through a lift check valve.

Installation is the same as for a lift check in that the flow must enter from under the seat. Construction of the seat and disk of a piston check valve is the same as for lift check valves.

Piston check valves are used primarily in conjunction with globe and angle valves in piping systems experiencing very frequent changes in flow direction. Valves of this type are used on water, steam, and air systems.

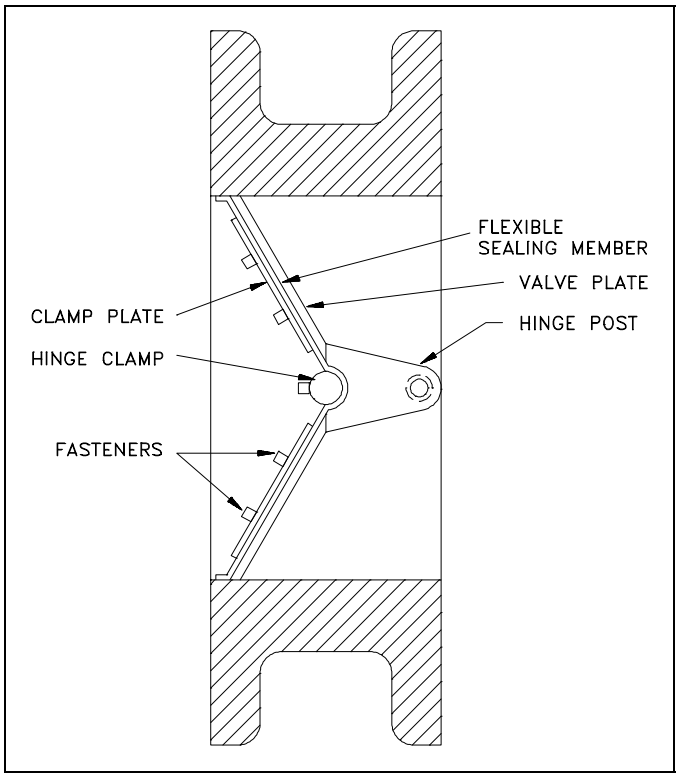

Figure 26 Butterfly Check Valve

Butterfly Check Valves

Butterfly check valves have a seating arrangement similar to the seating arrangement of butterfly valves. Flow characteristics through these check valves are similar to the flow characteristics through butterfly valves. Consequently, butterfly check valves are quite frequently used in systems using butterfly valves. In addition, the construction of the butterfly check valve body is such that ample space is provided for unobstructed movement of the butterfly valve disk within the check valve body without the necessity of installing spacers.

The butterfly check valve design is based on a flexible sealing member against the bore of the valve body at an angle of 45°. The short distance the disk must move from full open to full closed inhibits the "slamming" action found in some other types of check valves. Figure 26 illustrates the internal assembly of the butterfly check valve.

Because the flow characteristics are similar to the flow characteristics of butterfly valves, applications of these valves are much the same. Also, because of their relatively quiet operation they find application in heating, ventilation, and air conditioning systems. Simplicity of design also permits their construction in large diameters - up to 72 inches.

As with butterfly valves, the basic body design lends itself to the installation of seat liners constructed of many materials. This permits the construction of a corrosion-resistant valve at less expense than would be encountered if it were necessary to construct the entire body of the higher alloy or more expensive metal. This is particularly true in constructions such as those of titanium.

Flexible sealing members are available in Buna-N, Neoprene, Nordel, Hypalon, Viton, Tyon, Urethane, Butyl, Silicone, and TFE as standard, with other materials available on special order.

The valve body essentially is a length of pipe that is fitted with flanges or has threaded, grooved, or plain ends. The interior is bored to a fine finish. The flanged end units can have liners of various metals or plastics installed depending upon the service requirements. Internals and fasteners are always of the same material as the liner.

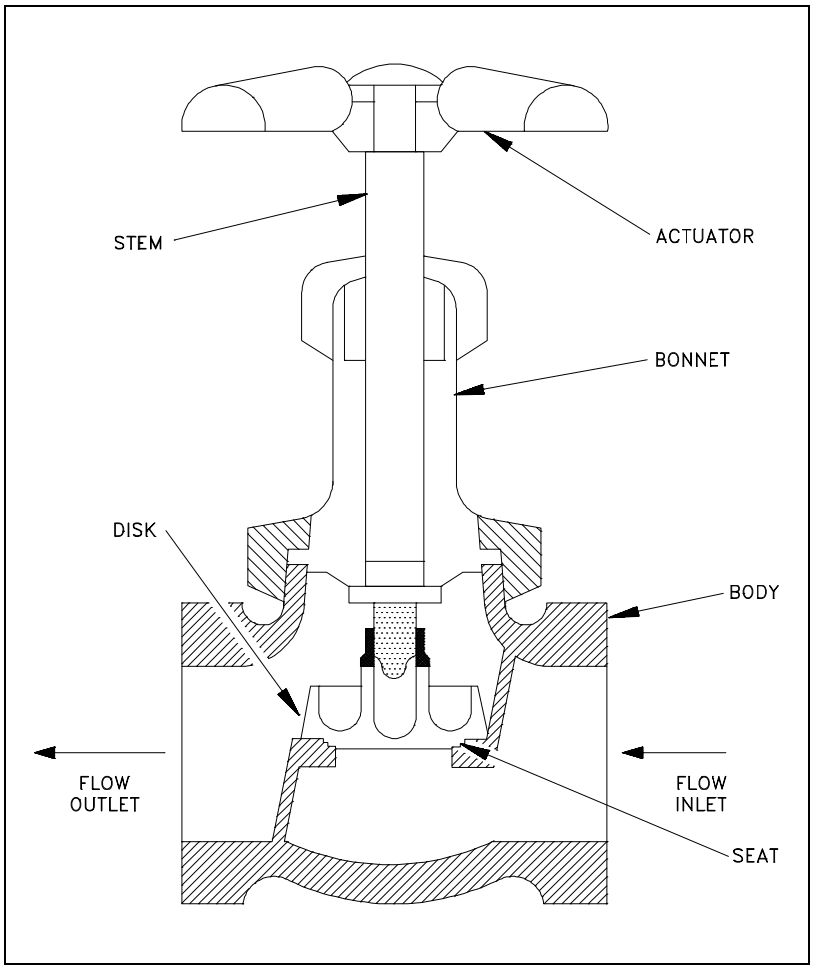

Figure 27 Stop Check Valve

Butterfly check valves may be installed horizontally or vertically with the vertical flow either upward or downward. Care should be taken to ensure that the valve is installed so that the entering flow comes from the hinge post end of the valve; otherwise, all flow will be stopped.

Stop Check Valves

A stop check valve, illustrated in Figure 27, is a combination of a lift check valve and a globe valve. It has a stem which, when closed, prevents the disk from coming off the seat and provides a tight seal (similar to a globe valve). When the stem is operated to the open position, the valve operates as a lift check. The stem is not connected to the disk and functions to close the valve tightly or to limit the travel of the valve disk in the open direction.

Relief and Safety Valves

Relief and safety valves prevent equipment damage by relieving accidental over-pressurization of fluid systems. The main difference between a relief valve and a safety valve is the extent of opening at the setpoint pressure.

A relief valve, illustrated in Figure 28, gradually opens as the inlet pressure increases above the setpoint. A relief valve opens only as necessary to relieve the over-pressure condition. A safety valve, illustrated in Figure 29, rapidly pops fully open as soon as the pressure setting is reached. A safety valve will stay fully open until the pressure drops below a reset pressure. The reset pressure is lower than the actuating pressure setpoint. The difference between the actuating pressure setpoint and the pressure at which the safety valve resets is called *blowdown*. Blowdown is expressed as a percentage of the actuating pressure setpoint.

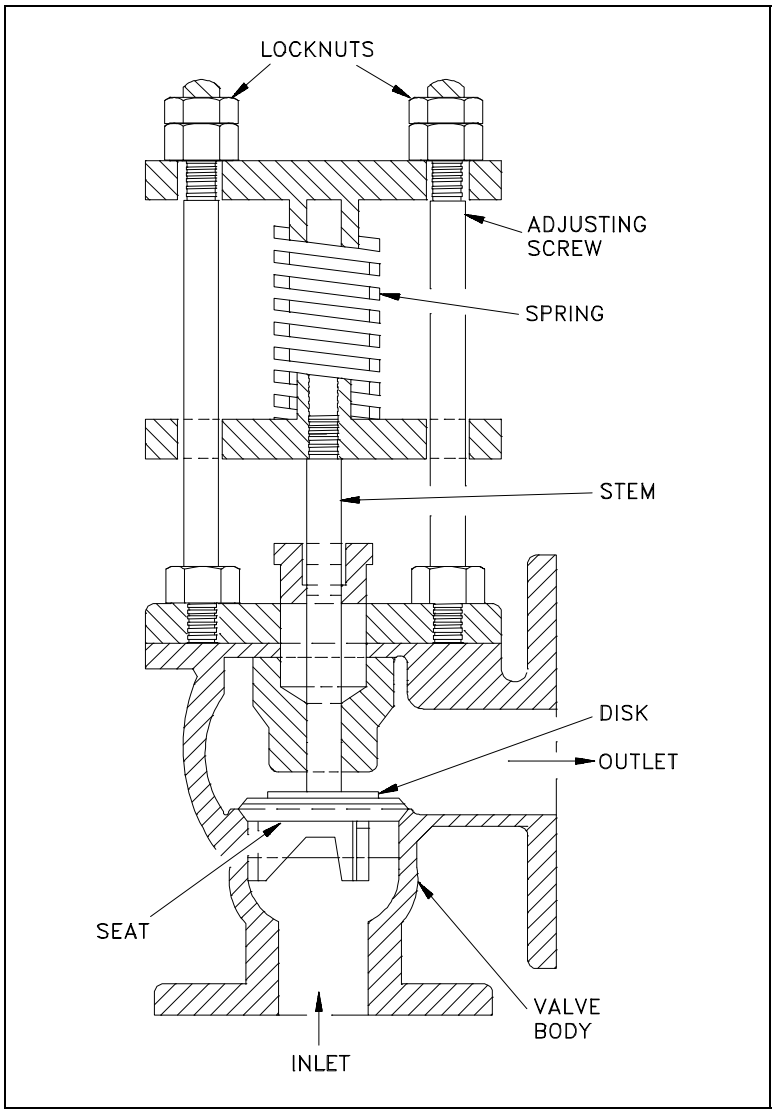

Figure 28 Relief Valve

Relief valves are typically used for incompressible fluids such as water or oil. Safety valves are typically used for compressible fluids such as steam or other gases. Safety valves can often be distinguished by the presence of an external lever at the top of the valve body, which is used as an operational check.

As indicated in Figure 29, system pressure provides a force that is attempting to push the disk of the safety valve off its seat. Spring pressure on the stem is forcing the disk onto the seat. At the pressure determined by spring compression, system pressure overcomes spring pressure and the relief valve opens. As system pressure is relieved, the valve closes when spring pressure again overcomes system pressure. Most relief and safety valves open against the force of a compression spring. The pressure setpoint is adjusted by turning the adjusting nuts on top of the yoke to increase or decrease the spring compression.

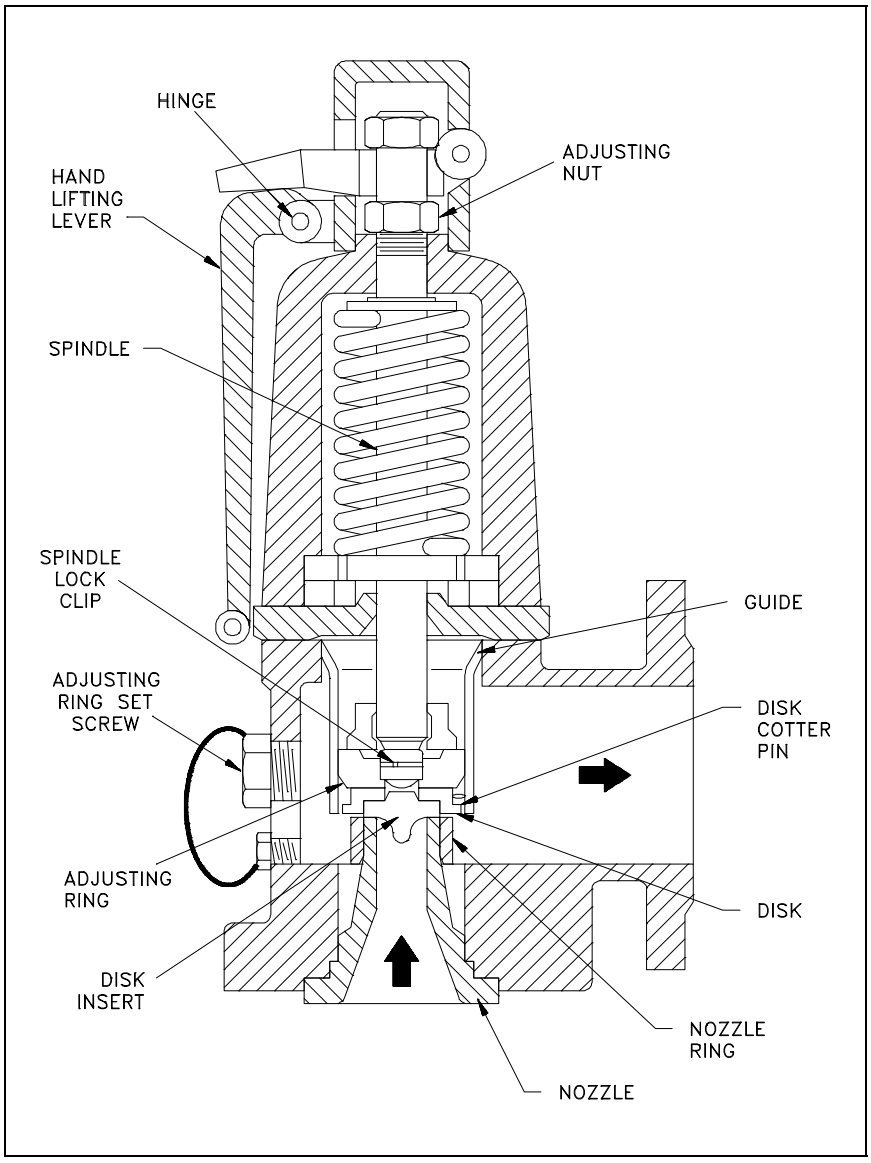

Figure 29 Safety Valve

Pilot-Operated Relief Valves

Pilot-operated relief valves are designed to maintain pressure through the use of a small passage to the top of a piston that is connected to the stem such that system pressure closes the main relief valve. When the small pilot valve opens, pressure is relieved from the piston, and system pressure under the disk opens the main relief valve. Such pilot valves are typically solenoid-operated, with the energizing signal originating from pressure measuring systems.

Summary

The following important information in this chapter is summarized below.

Types of Valves Summary

- Gate valves are generally used in systems where low flow resistance for a fully open valve is desired and there is no need to throttle the flow.
- Globe valves are used in systems where good throttling characteristics and low seat leakage are desired and a relatively high head loss in an open valve is acceptable.
- Ball valves allow quick, quarter turn on-off operation and have poor throttling characteristics.
- Plug valves are often used to direct flow between several different ports through use of a single valve.
- Diaphragm valves and pinch valves are used in systems where it is desirable for the entire operating mechanism to be completely isolated from the fluid.
- Butterfly valves provide significant advantages over other valve designs in weight, space, and cost for large valve applications.
- Check valves automatically open to allow flow in one direction and seat to prevent flow in the reverse direction.
- A stop check valve is a combination of a lift check valve and a globe valve and incorporates the characteristics of both.
- Safety/relief valves are used to provide automatic overpressurization protection for a system.

VALVE ACTUATORS

Some type of actuator is necessary to allow for the positioning of a valve. Actuators vary from simple manual handwheels to relatively complex electrical and hydraulic manipulators.

EO 1.6 DESCRIBE the construction and principle of operation for the following types of valve actuators:

a. Manual
b. Electric motor
c. Pneumatic
d. Hydraulic
e. Solenoid

Introduction

Valve actuators are selected based upon a number of factors including torque necessary to operate the valve and the need for automatic actuation. Types of actuators include manual handwheel, manual lever, electrical motor, pneumatic, solenoid, hydraulic piston, and self-actuated. All actuators except manual handwheel and lever are adaptable to automatic actuation.

Manual, Fixed, and Hammer Actuators

Manual actuators are capable of placing the valve in any position but do not permit automatic operation. The most common type mechanical actuator is the handwheel. This type includes handwheels fixed to the stem, hammer handwheels, and handwheels connected to the stem through gears.

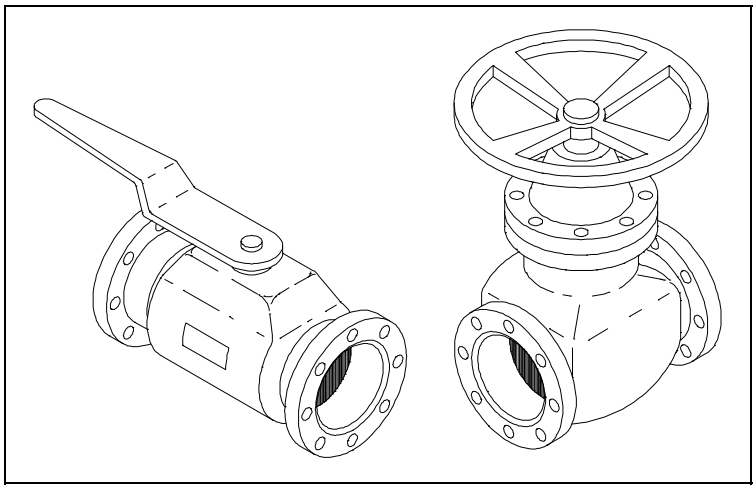

Figure 30 Fixed Handwheel

Handwheels Fixed to Stem

As illustrated in Figure 30, handwheels fixed to the stem provide only the mechanical advantage of the wheel. When these valves are exposed to high operating temperatures, valve binding makes operation difficult.

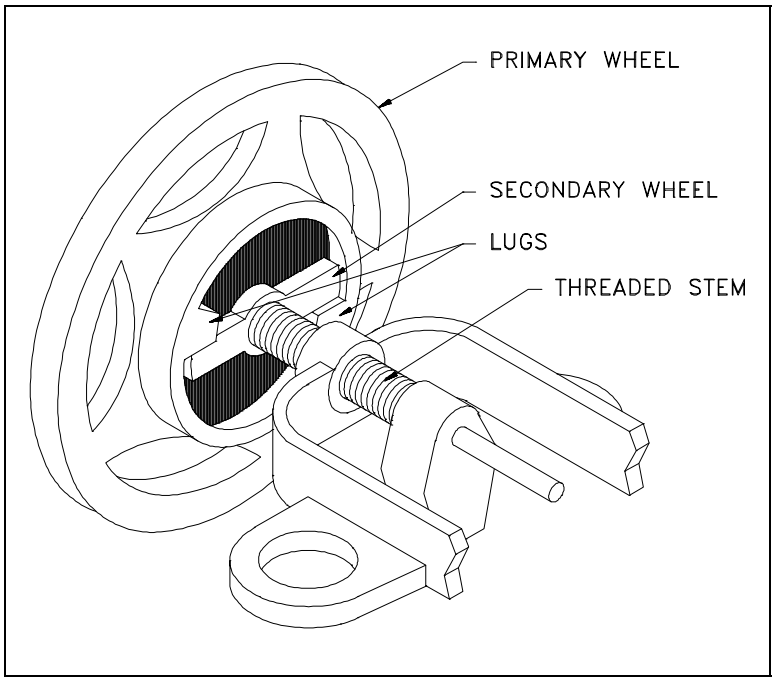

Figure 31 Hammer Handwheel

Hammer Handwheel

As illustrated in Figure 31, the hammer handwheel moves freely through a portion of its turn and then hits against a lug on a secondary wheel. The secondary wheel is attached to the valve stem. With this arrangement, the valve can be pounded shut for tight closure or pounded open if it is stuck shut.

Gears

If additional mechanical advantage is necessary for a manually-operated valve, the valve bonnet is fitted with manually-operated gear heads as illustrated in Figure 32. A special wrench or handwheel attached to the pinion shaft permits one individual to operate the valve when two individuals might be needed without the gear advantage. Because several turns of the pinion are necessary to produce one turn of the valve stem, the operating time of large valves is exceptionally long. The use of portable air motors connected to the pinion shaft decreases the valve operating time.

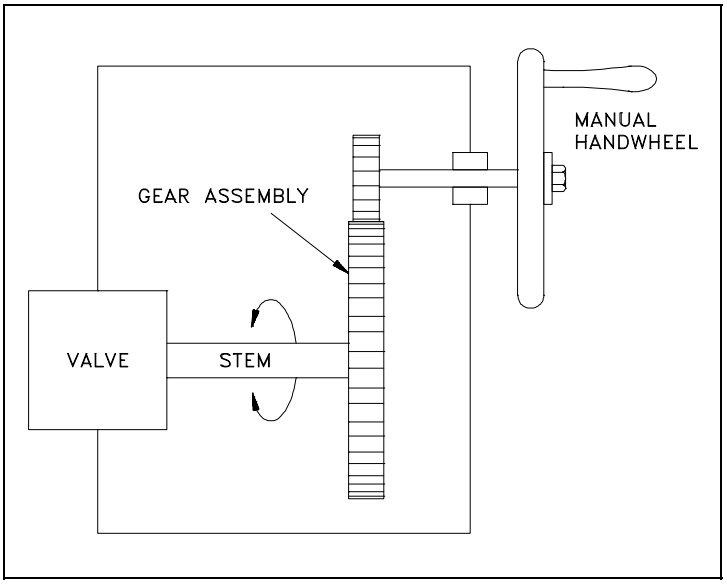

Figure 32 Manual Gear Head

Electric Motor Actuators

Electric motors permit manual, semi-automatic, and automatic operation of the valve. Motors are used mostly for open-close functions, although they are adaptable to positioning the valve to any point opening as illustrated in Figure 33. The motor is usually a, reversible, high speed type connected through a gear train to reduce the motor speed and thereby increase the torque at the stem. Direction of motor rotation determines direction of disk motion. The electrical actuation can be semi-automatic, as when the motor is started by a control system. A handwheel, which can be engaged to the gear train, provides for manual operating of the valve. Limit switches are normally provided to stop the motor automatically at full open and full closed valve positions. Limit switches are operated either physically by position of the valve or torsionally by torque of the motor.

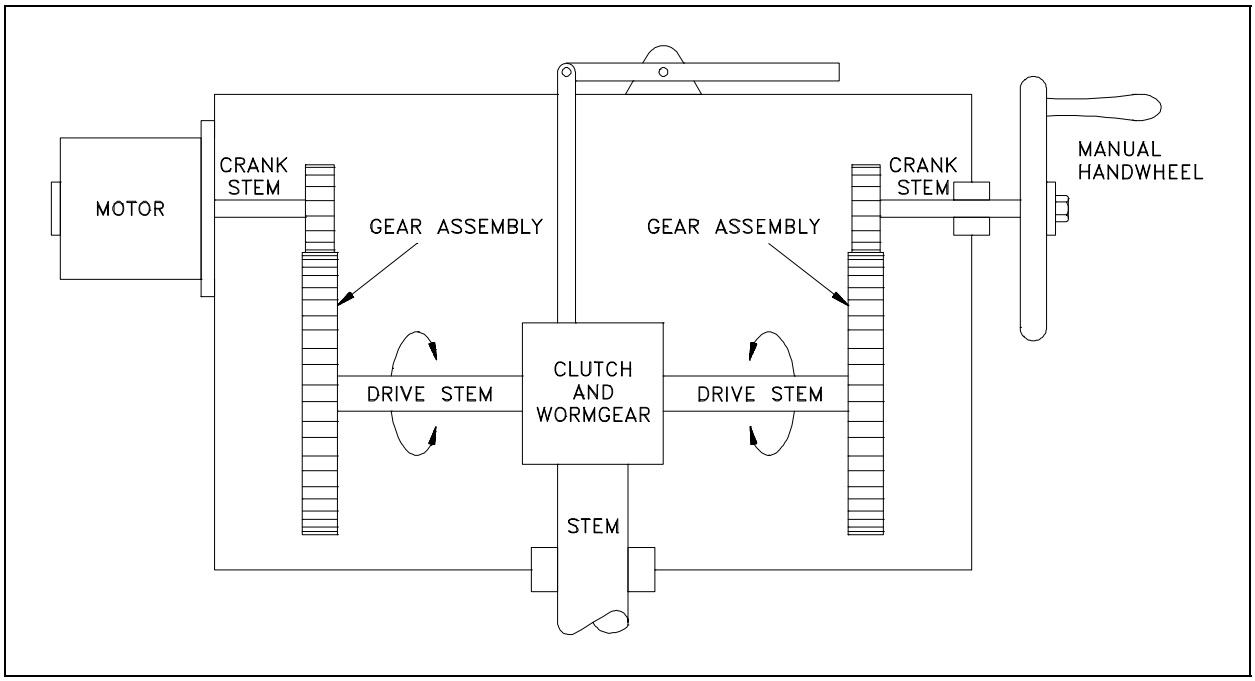

Figure 33 Electric Motor Actuator

Pneumatic Actuators

Pneumatic actuators as illustrated in Figure 34 provide for automatic or semi-automatic valve operation. These actuators translate an air signal into valve stem motion by air pressure acting on a diaphragm or piston connected to the stem. Pneumatic actuators are used in throttle valves for open-close positioning where fast action is required. When air pressure closes the valve and spring action opens the valve, the actuator is termed direct-acting. When air pressure opens the valve and spring action closes the valve, the actuator is termed reverse-acting. Duplex actuators have air supplied to both sides of the diaphragm. The differential pressure across the diaphragm positions the valve stem. Automatic operation is provided when the air signals are automatically controlled by circuitry. Semi-automatic operation is provided by manual switches in the circuitry to the air control valves.

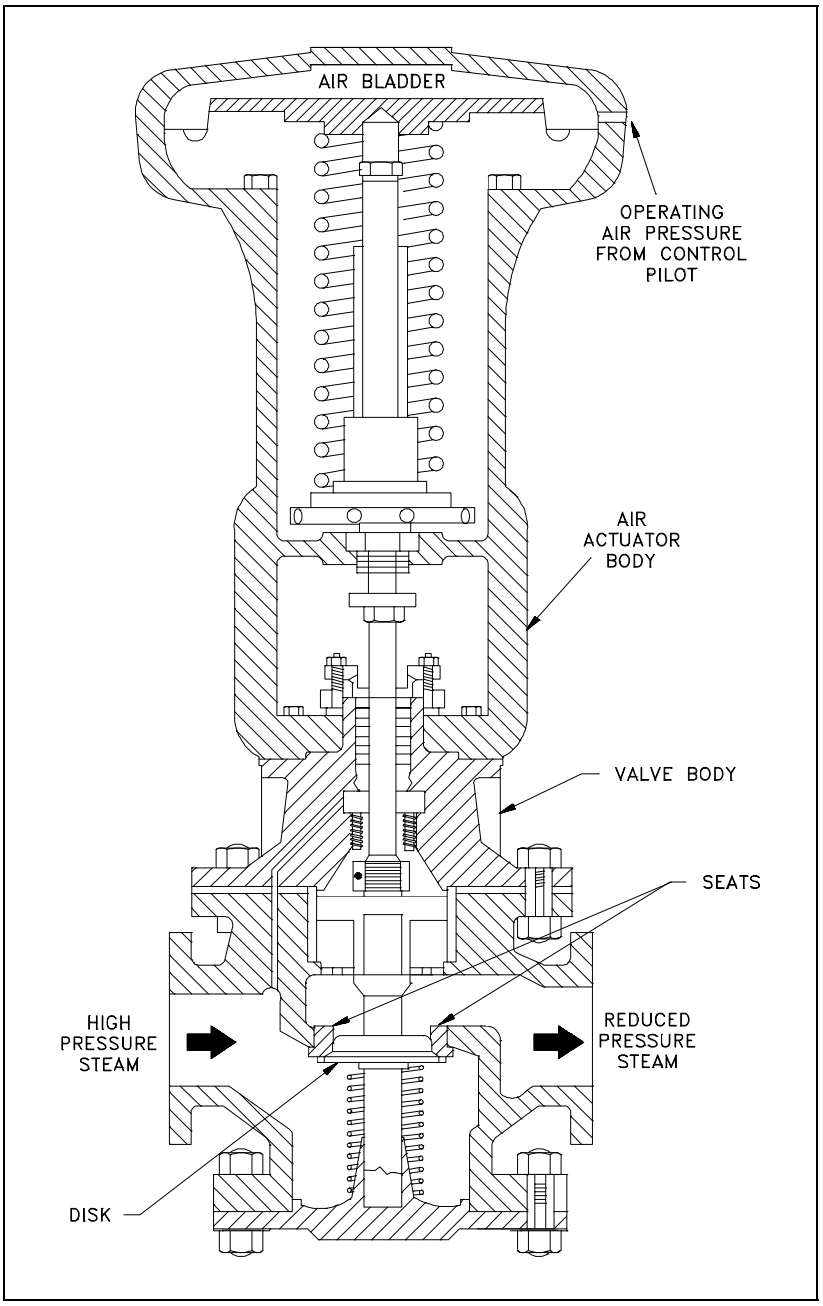

Figure 34 Pneumatic Actuator

Hydraulic Actuators

Hydraulic actuators provide for semi-automatic or automatic positioning of the valve, similar to the pneumatic actuators. These actuators use a piston to convert a signal pressure into valve stem motion. Hydraulic fluid is fed to either side of the piston while the other side is drained or bled. Water or oil is used as the hydraulic fluid. Solenoid valves are typically used for automatic control of the hydraulic fluid to direct either opening or closing of the valve. Manual valves can also be used for controlling the hydraulic fluid; thus providing semi-automatic operation.

Self-Actuated Valves

Self-actuated valves use the system fluid to position the valve. Relief valves, safety valves, check valves, and steam traps are examples of self-actuated valves. All of these valves use some characteristic of the system fluid to actuate the valve. No source of power outside the system fluid energy is necessary for operation of these valves.

Solenoid Actuated Valves

Solenoid actuated valves provide for automatic open-close valve positioning as illustrated in Figure 35. Most solenoid actuated valves also have a manual override that permits manual positioning of the valve for as long as the override is manually positioned. Solenoids position the valve by attracting a magnetic slug attached to the valve stem. In single solenoid valves, spring pressure acts against the motion of the slug when power is applied to the solenoid. These valves can be arranged such that power to the solenoid either opens or closes the valve. When power to the solenoid is removed, the spring returns the valve to the opposite position. Two solenoids can be used to provide for both opening and closing by applying power to the appropriate solenoid.

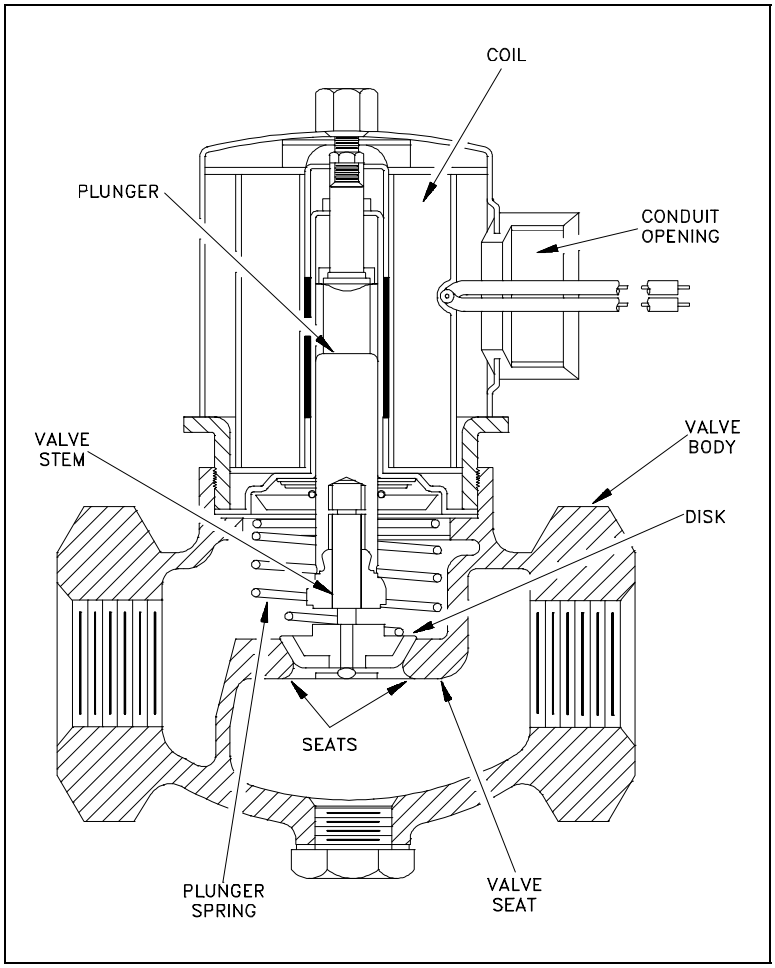

Figure 35 Solenoid Actuated Valve

Single solenoid valves are termed fail open or fail closed depending on the position of the valve with the solenoid de-energized. Fail open solenoid valves are opened by spring pressure and closed by energizing the solenoid. Fail closed solenoid valves are closed by spring pressure and opened by energizing the solenoid. Double solenoid valves typically fail "as is." That is, the valve position does not change when both solenoids are de-energized.

One application of solenoid valves is in air systems such as those used to supply air to pneumatic valve actuators. The solenoid valves are used to control the air supply to the pneumatic actuator and thus the position of the pneumatic actuated valve.

Speed of Power Actuators

Plant safety considerations dictate valve speeds for certain safety-related valves. Where a system must be very quickly isolated or opened, very fast valve actuation is required. Where the opening of a valve results in injection of relatively cold water to a hot system, slower opening is necessary to minimize thermal shock. Engineering design selects the actuator for safety-related valves based upon speed and power requirements and availability of energy to the actuator.

In general, fastest actuation is provided by hydraulic, pneumatic, and solenoid actuators. However, solenoids are not practical for large valves because their size and power requirements would be excessive. Also, hydraulic and pneumatic actuators require a system for providing hydraulic or pneumatic energy. The speed of actuation in either case can be set by installing appropriately sized orifices in the hydraulic or pneumatic lines. In certain cases, the valve is closed by spring pressure, which is opposed by hydraulic or pneumatic pressure to keep the valve open.

Electrical motors provide relatively fast actuation. Actual valve speed is set by the combination of motor speed and gear ratio. This combination can be selected to provide full valve travel within a range from about two seconds to several seconds.

Valve Position Indication

Operators require indication of the position of certain valves to permit knowledgeable operation of the plant. For such valves, remote valve position indication is provided in the form of position lights that indicate if valves are open or closed. Remote valve position indication circuits use a position detector that senses stem and disk position or actuator position. One type of position detector is the mechanical limit switch, which is physically operated by valve movement.

Another type is magnetic switches or transformers that sense movement of their magnetic cores, which are physically operated by valve movement.

Local valve position indication refers to some visually discernable characteristic of the valve that indicates valve position. Rising stem valve position is indicated by the stem position. Nonrising stem valves sometimes have small mechanical pointers that are operated by the valve actuator simultaneously with valve operation. Power actuated valves typically have a mechanical pointer that provides local valve position indication. On the other hand, some valves do not have any feature for position indication.

Summary

The important information in this chapter is summarized below.

Valve Actuators Summary

- Manual actuators are the most common type of valve actuators. Manual actuators include handwheels attached to the valve stem directly and handwheels attached through gears to provide a mechanical advantage.
- Electric motor actuators consist of reversible electric motors connected to the valve stem through a gear train that reduces rotational speed and increases torque.
- Pneumatic actuators use air pressure on either one or both sides of a diaphragm to provide the force to position the valve.
- Hydraulic actuators use a pressurized liquid on one or both sides of a piston to provide the force required to position the valve.
- Solenoid actuators have a magnetic slug attached to the valve stem. The force to position the valve comes from the magnetic attraction between the slug on the valve stem and the coil of the electromagnet in the valve actuator.

Department of Energy
Fundamentals Handbook

MECHANICAL SCIENCE
Module 5
Miscellaneous Mechanical Components

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TERMINAL OBJECTIVE

1.0 Without references, **DESCRIBE** the purpose, construction, and operation of miscellaneous mechanical components.

ENABLING OBJECTIVES

1.1 **STATE** the three common types of air compressors.

1.2 **DESCRIBE** the basic operation of the following types of air compressors:

a. Reciprocating
b. Centrifugal
c. Rotary

1.3 **STATE** the reason for using cooling systems in air compressors.

1.4 **STATE** three hazards associated with pressurized air systems.

1.5 Given the appropriate information, **CALCULATE** the pressure or force achieved in a hydraulic piston.

1.6 **DESCRIBE** the basic operation of a hydraulic system.

1.7 **DESCRIBE** the basic operation of a boiler.

1.8 **IDENTIFY** the following components of a typical boiler:

a. Steam drum
b. Distribution header(s)
c. Combustion chamber
d. Downcomer
e. Risers

1.9 **STATE** the purpose of cooling towers.

1.10 **DESCRIBE** the operation of the following types of cooling towers.

a. Forced draft
b. Natural convection

ENABLING OBJECTIVES (Cont.)

1.11 **STATE** the purpose of a demineralizer.

1.12 **STATE** the four purposes of a pressurizer.

1.13 **DEFINE** the following terms attributable to a dynamic pressurizer:

a. Spray nozzle
b. Insurge
c. Outsurge
d. Surge volume

1.14 **STATE** the purpose and general operation of a steam trap.

1.15 **IDENTIFY** the following types of steam traps:

a. Ball float steam trap
b. Bellow steam trap
c. Bucket steam trap
d. Impulse steam trap

1.16 **DESCRIBE** each of the following types of strainers and filters, including an example of typical use.

a. Cartridge filters
b. Precoated filters
c. Deep-bed filters
d. Bucket strainer
e. Duplex strainer

1.17 **EXPLAIN** the application and operation of a strainer or filter backwash.

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AIR COMPRESSORS

The purpose of an air compressor is to provide a continuous supply of pressurized air. This chapter will describe the various types of compressors and their basic operation.

EO 1.1 STATE the three common types of air compressors.

EO 1.2 DESCRIBE the basic operation of the following types of air compressors:

a. Reciprocating
b. Centrifugal
c. Rotary

EO 1.3 STATE the reason for using cooling systems in air compressors.

EO 1.4 STATE three hazards associated with pressurized air systems.

Introduction

Air compressors of various designs are used widely throughout DOE facilities in numerous applications. Compressed air has numerous uses throughout a facility including the operation of equipment and portable tools. Three types of designs include reciprocating, rotary, and centrifugal air compressors.

Reciprocating Compressors

The reciprocating air compressor, illustrated in Figure 1, is the most common design employed today.

The reciprocating compressor normally consists of the following elements.

a. The compressing element, consisting of air cylinders, heads and pistons, and air inlet and discharge valves.

b. A system of connecting rods, piston rods, crossheads, and a crankshaft and flywheel for transmitting the power developed by the driving unit to the air cylinder piston.

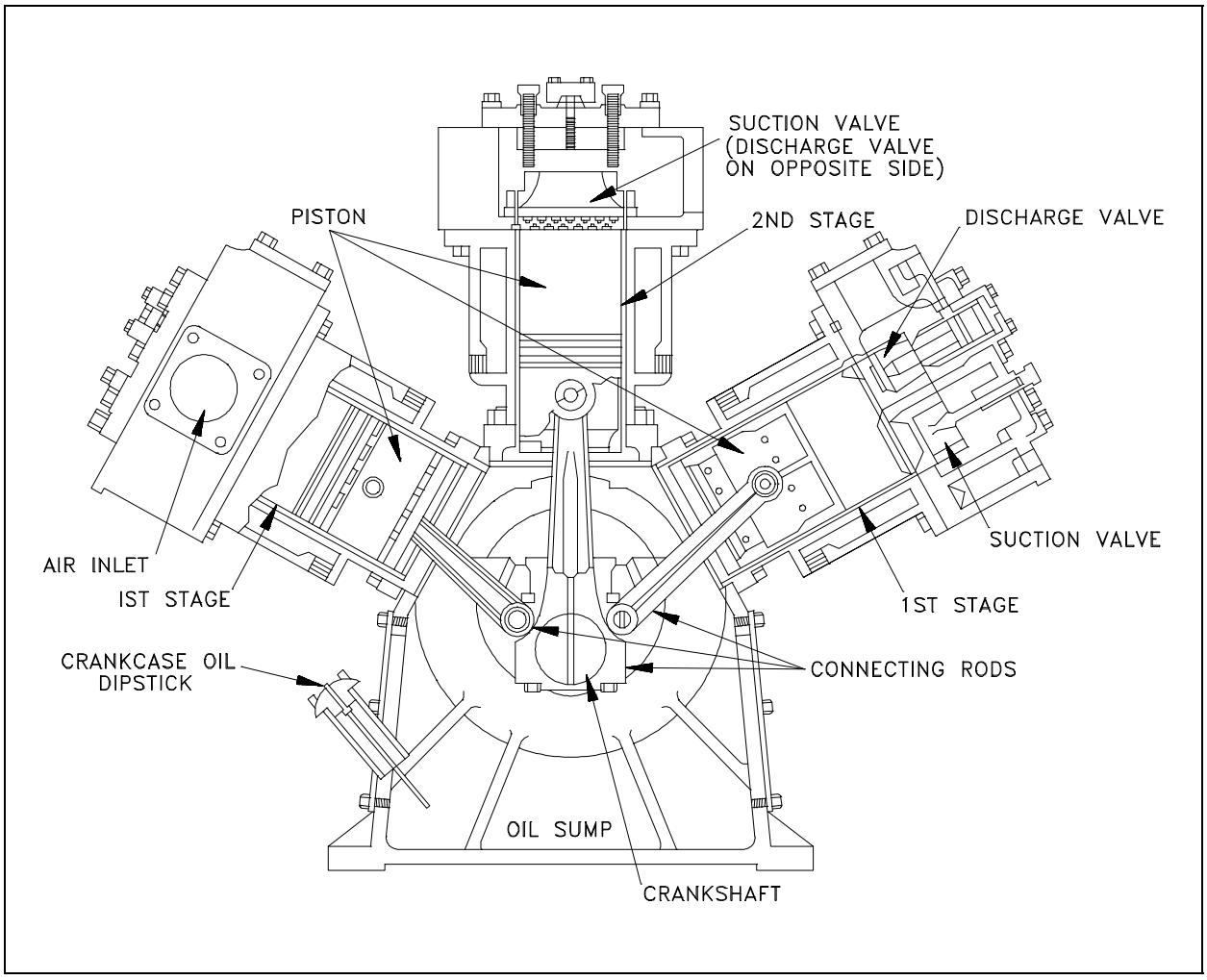

Figure 1 Reciprocating Air Compressor

c. A self-contained lubricating system for bearings, gears, and cylinder walls, including a reservoir or sump for the lubricating oil, and a pump, or other means of delivering oil to the various parts. On some compressors a separate force-fed lubricator is installed to supply oil to the compressor cylinders.

d. A regulation or control system designed to maintain the pressure in the discharge line and air receiver (storage tank) within a predetermined range of pressure.

e. An unloading system, which operates in conjunction with the regulator, to reduce or eliminate the load put on the prime mover when starting the unit.

A section of a typical reciprocating single-stage, single-acting compressor cylinder is shown in Figure 2. Inlet and discharge valves are located in the clearance space and connected through ports in the cylinder head to the inlet and discharge connections.

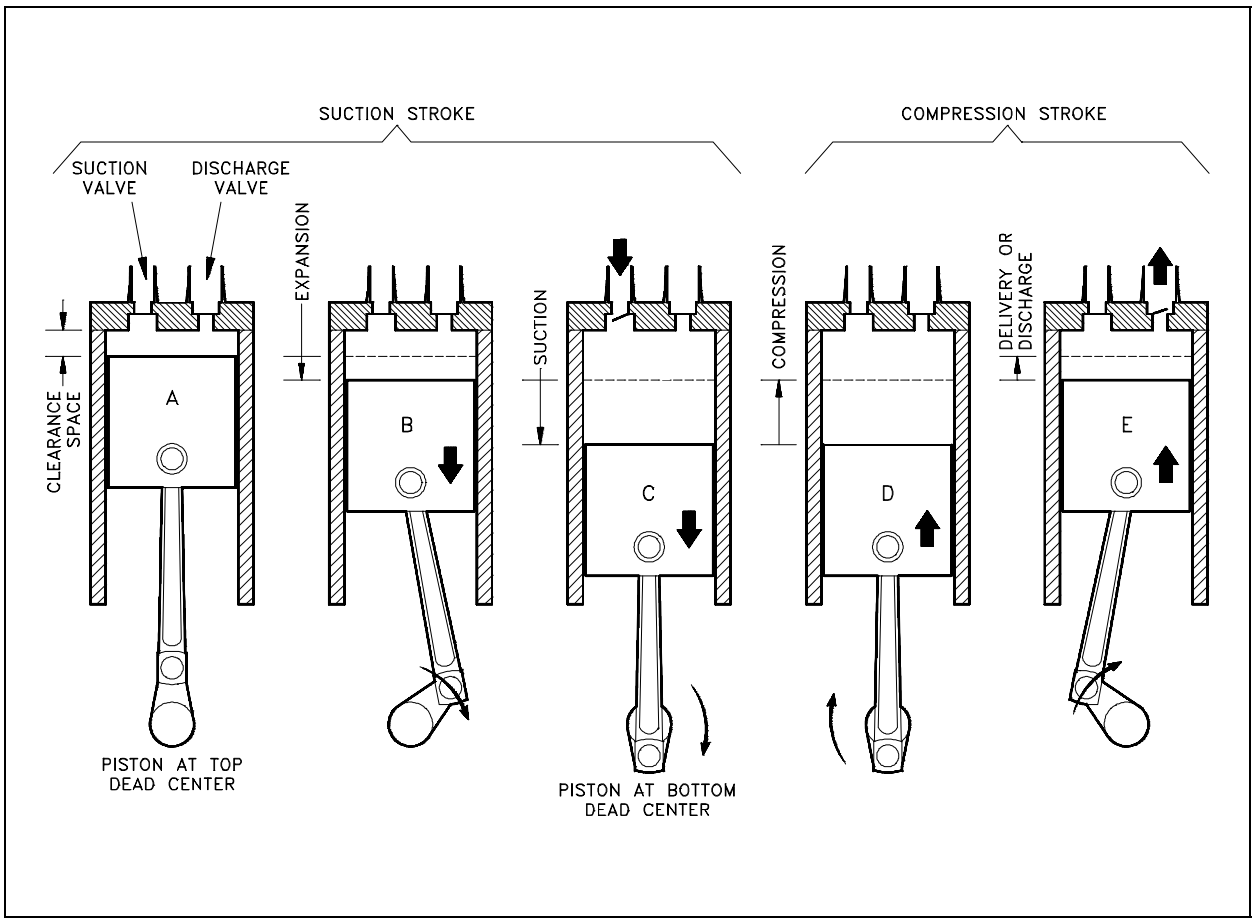

Figure 2 Single-Acting Air Compressor Cylinder

During the suction stroke the compressor piston starts its downward stroke and the air under pressure in the clearance space rapidly expands until the pressure falls below that on the opposite side of the inlet valve (Figures 2B and 2C). This difference in pressure causes the inlet valve to open into the cylinder until the piston reaches the bottom of its stroke (Figure 2C).

During the compression stroke the piston starts upward, compression begins, and at point D has reached the same pressure as the compressor intake. The spring-loaded inlet valve then closes. As the piston continues upward, air is compressed until the pressure in the cylinder becomes great enough to open the discharge valve against the pressure of the valve springs and the pressure of the discharge line (Figure 2E). From this point, to the end of the stroke (Figures 2E and 2A), the air compressed within the cylinder is discharged at practically constant pressure.

Rotary Compressors

The rotary compressor is adaptable to direct drive by induction motors or multicylinder gasoline or diesel engines. The units are compact, relatively inexpensive, and require a minimum of operating attention and maintenance. They occupy a fraction of the space and weight of a reciprocating machine of equivalent capacity. Rotary compressor units are classified into three general groups, slide vane-type, lobe-type, and liquid seal ring-type.

The rotary slide vane-type, as illustrated in Figure 3, has longitudinal vanes, sliding radially in a slotted rotor mounted eccentrically in a cylinder. The centrifugal force carries the sliding vanes against the cylindrical case with the vanes forming a number of individual longitudinal cells in the eccentric annulus between the case and rotor. The suction port is located where the longitudinal cells are largest. The size of each cell is reduced by the eccentricity of the rotor as the vanes approach the discharge port, thus compressing the air.

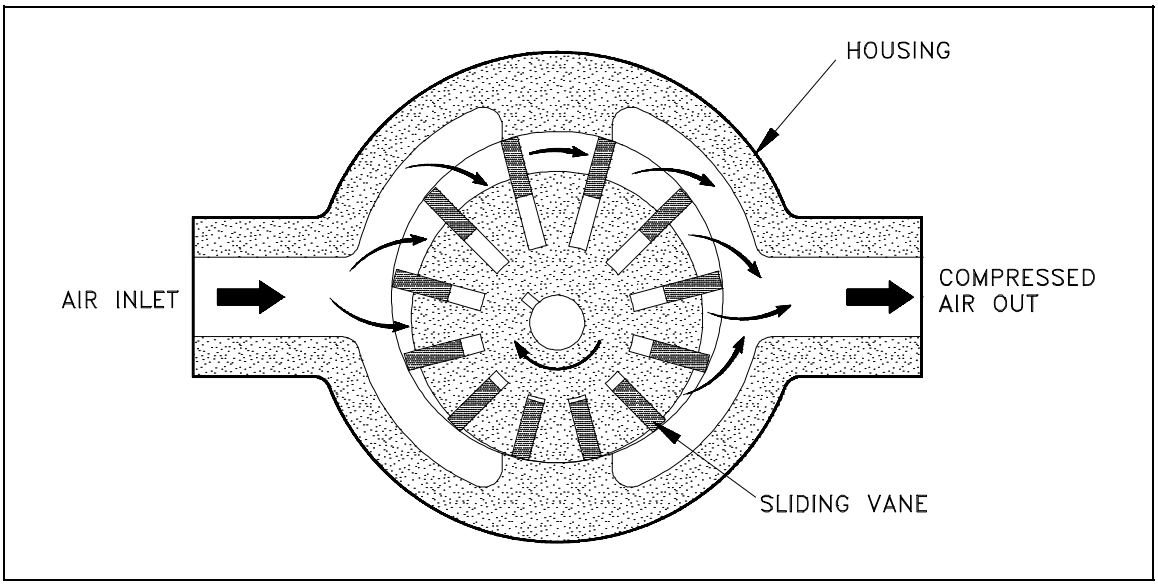

Figure 3 Rotary Slide Vane Air Compressor

The rotary lobe-type, illustrated in Figure 4, features two mating lobe-type rotors mounted in a case. The lobes are gear driven at close clearance, but without metal-to-metal contact. The suction to the unit is located where the cavity made by the lobes is largest. As the lobes rotate, the cavity size is reduced, causing compression of the vapor within. The compression continues until the discharge port is reached, at which point the vapor exits the compressor at a higher pressure.

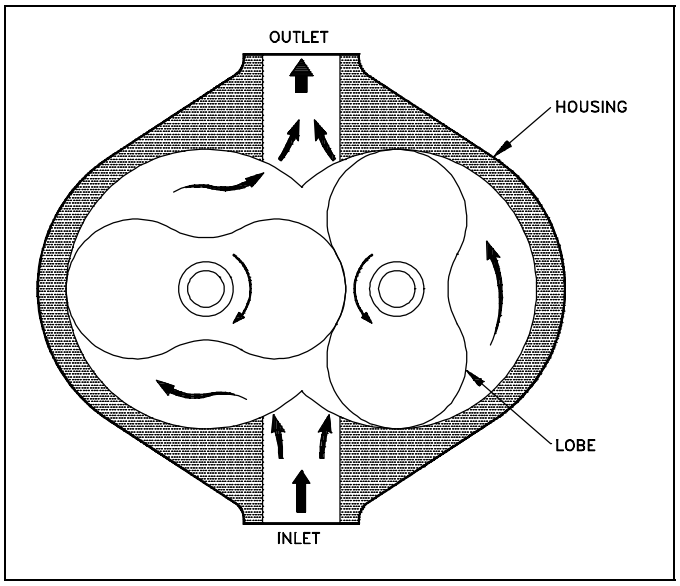

Figure 4 Rotary Lobe Air Compressor

The rotary liquid seal ring-type, illustrated in Figure 5, features a forward inclined, open impeller, in an oblong cavity filled with liquid. As the impeller rotates, the centrifugal force causes the seal liquid to collect at the outer edge of the oblong cavity. Due to the oblong configuration of the compressor case, large longitudinal cells are created and reduced to smaller ones. The suction port is positioned where the longitudinal cells are the largest, and for the discharge port, where they are smallest, thus causing the vapor within the cell to compress as the rotor rotates. The rotary liquid seal compressor is frequently used in specialized applications for the compression of extremely corrosive and exothermic gasses and is commonly used in commercial nuclear plants as a means of establishing initial condenser vacuum.

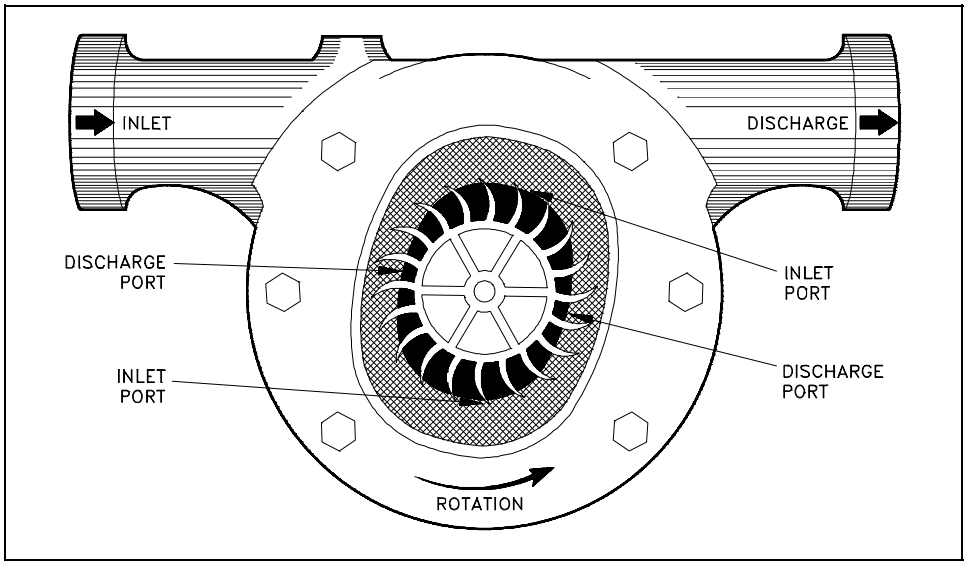

Figure 5 Rotary Liquid Seal Ring Air Compressor

Centrifugal Compressors

The centrifugal compressor, originally built to handle only large volumes of low pressure gas and air (maximum of 40 psig), has been developed to enable it to move large volumes of gas with discharge pressures up to 3,500 psig. However, centrifugal compressors are now most frequently used for medium volume and medium pressure air delivery. One advantage of a centrifugal pump is the smooth discharge of the compressed air.

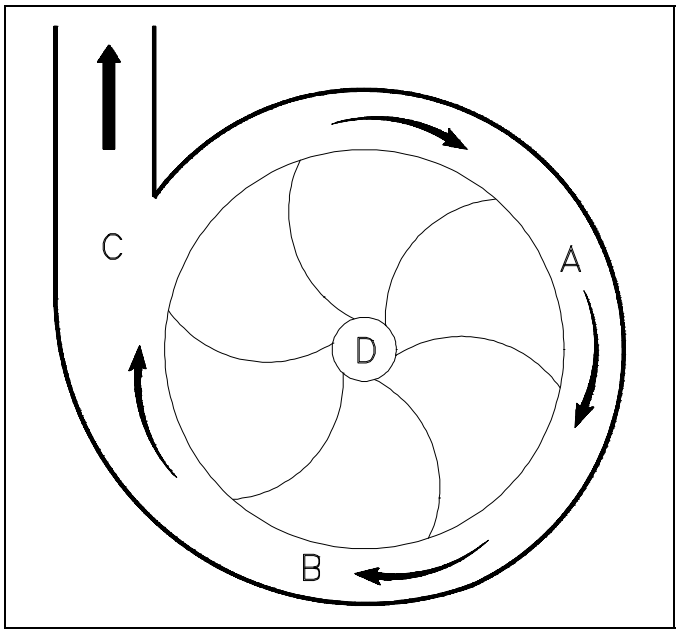

Figure 6 Simplified Centrifugal Pump

The centrifugal force utilized by the centrifugal compressor is the same force utilized by the centrifugal pump. The air particles enter the eye of the impeller, designated D in Figure 6. As the impeller rotates, air is thrown against the casing of the compressor. The air becomes compressed as more and more air is thrown out to the casing by the impeller blades. The air is pushed along the path designated A, B, and C in Figure 6. The pressure of the air is increased as it is pushed along this path. Note in Figure 6 that the impeller blades curve forward, which is opposite to the backward curve used in typical centrifugal liquid pumps. Centrifugal compressors can use a variety of blade orientation including both forward and backward curves as well as other designs.

There may be several stages to a centrifugal air compressor, as in the centrifugal pump, and the result would be the same; a higher pressure would be produced. The air compressor is used to create compressed or high pressure air for a variety of uses. Some of its uses are pneumatic control devices, pneumatic sensors, pneumatic valve operators, pneumatic motors, and starting air for diesel engines.

Compressor Coolers

The amount of moisture that air can hold is inversely proportional to the pressure of the air. As the pressure of the air increases, the amount of moisture that air can hold decreases. The amount of moisture that air can hold is also proportional to the temperature of the air. As the temperature of the air increases, the amount of moisture it can hold increases. However, the pressure change of compressed air is larger than the temperature change of the compressed air. This causes the moisture in the air to condense. Moisture in compressed air systems can cause serious damage. The condensed moisture can cause corrosion, water hammers, and freeze damage; therefore, it is important to avoid moisture in compressed air systems. Coolers are used to minimize the problems caused by heat and moisture in compressed air systems.

Coolers used on the discharge of a compressor are called aftercoolers. Their purpose is to remove the heat generated during the compression of the air. The decrease in temperature promotes the condensing of any moisture present in the compressed air. This moisture is collected in condensate traps that are either automatically or manually drained.

If the compressor is multi-staged, there may be an intercooler, which is usually located after the first stage discharge and before the second stage suction. The principle of the intercooler is the same as that of the aftercoolers. The result is drier, cooler, compressed air. The structure of a particular cooler depends on the pressure and volume of the air it cools. Figure 7 illustrates a typical compressor air cooler. Air coolers are used because drier compressed air helps prevent corrosion and cooler compressed air allows more air to be compressed for a set volume.

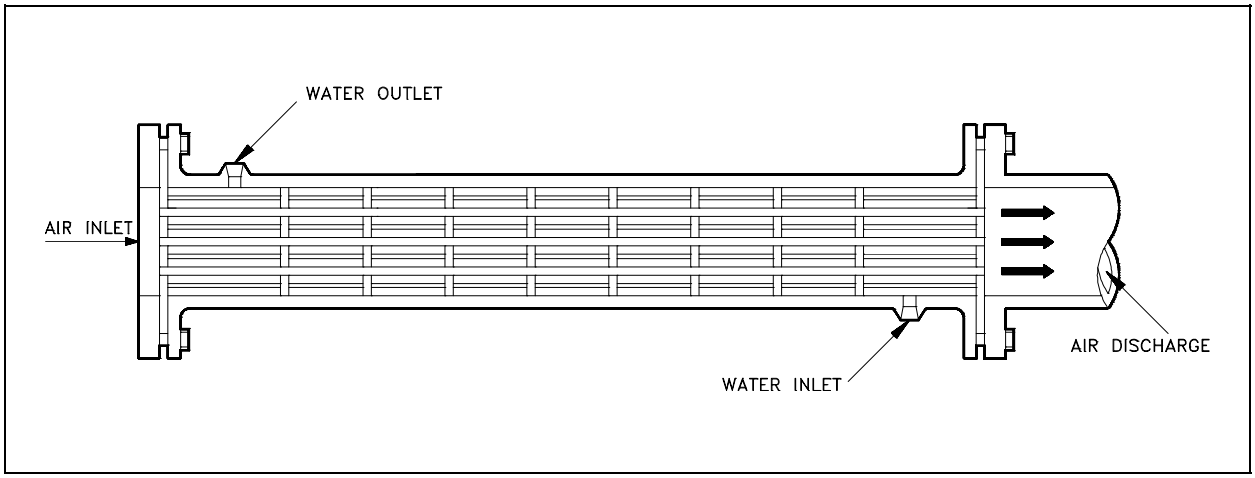

Figure 7 Compressor Air Cooler

Hazards of Compressed Air

People often lack respect for the power in compressed air because air is so common and is often viewed as harmless. At sufficient pressures, compressed air can cause serious damage if handled incorrectly. To minimize the hazards of working with compressed air, all safety precautions should be followed closely.

Small leaks or breaks in the compressed air system can cause minute particles to be blown at extremely high speeds. Always wear safety glasses when working in the vicinity of any compressed air system. Safety goggles are recommended if contact lenses are worn.

Compressors can make an exceptional amount of noise while running. The noise of the compressor, in addition to the drain valves lifting, creates enough noise to require hearing protection. The area around compressors should normally be posted as a hearing protection zone.

Pressurized air can do the same type of damage as pressurized water. Treat all operations on compressed air systems with the same care taken on liquid systems. Closed valves should be slowly cracked open and both sides should be allowed to equalize prior to opening the valve further. Systems being opened for maintenance should always be depressurized before work begins.

Great care should be taken to keep contaminants from entering air systems. This is especially true for oil. Oil introduced in an air compressor can be compressed to the point where detonation takes place in a similar manner as that which occurs in a diesel engine. This detonation can cause equipment damage and personnel injury.

Summary

The important information in this chapter is summarized below.

Air Compressors Summary

- The three common types of air compressors are reciprocating, rotary, and centrifugal.
- The single-stage reciprocating compressor has a piston that moves downward during the suction stroke, expanding the air in the cylinder. The expanding air causes pressure in the cylinder to drop. When the pressure falls below the pressure on the other side of the inlet valve, the valve opens and allows air in until the pressure equalizes across the inlet valve. The piston bottoms out and then begins a compression stroke. The upward movement of the piston compresses the air in the cylinder, causing the pressure across the inlet valve to equalize and the inlet valve to reseat. The piston continues to compress air during the remainder of the upward stroke until the cylinder pressure is great enough to open the discharge valve against the valve spring pressure. Once the discharge valve is open, the air compressed in the cylinder is discharged until the piston completes the stroke.

Air Compressors Summary (Cont.)

- The centrifugal force utilized by the centrifugal compressors is the same force utilized by the centrifugal pumps. The air particles enter the eye of the impeller. As the impeller rotates, air is thrown against the casing of the compressor. The air becomes compressed as more and more air is thrown out to the casing by the impeller blades. The air is pushed along the path on the inner wall of the casing. The pressure of the air is increased as it is pushed along this path. There could be several stages to a centrifugal air compressor just as in the centrifugal pump, resulting in higher pressure.

- Rotary compressors are driven by a direct drive that rotates a mechanism (impellers, vanes, or lobes) that compresses the air being pumped. The actual compression of the air takes place due either to centrifugal forces or a diminishing air space as the impellers rotate.

- Cooling systems are required in compressed air systems to remove any heat added by the compression. The advantages to cooling the compressed air are that cool air takes less space and holds less moisture. This reduces corrosion and allows more air to be compressed into a given volume.

- Hazards associated with compressed air are similar to hazards of any high pressure system. Three general hazards include the following.

  Small leaks or breaks can cause minute particles to be blown at speeds high enough to cause damage. Goggles or safety glasses should be worn when working around compressed gas.

  The compressors, especially larger ones, can be quite noisy when running. The cycling of automatic drain valves contributes noise as well. Hearing protection should be worn around compressors.

  Pressure swings may cause system damage. Closed valves in a compressed air system should be slowly cracked open and the pressure should be allowed to equalize prior to opening the valve further. Systems should be depressurized prior to opening for maintenance. Oil should be kept out of air systems to prevent possible explosions.

HYDRAULICS

Many machines and processes use a fluid for developing a force to move or hold an object, or to control an action. The term hydraulic refers to a liquid. A number of fluids can be used for developing the force. In a hydraulic system, oil, water, or other liquids can be used. Oil is the most common.

EO 1.5 Given the appropriate information, CALCULATE the pressure or force achieved in a hydraulic piston.

EO 1.6 DESCRIBE the basic operation of a hydraulic system.

Introduction

Although any liquid can be used in a hydraulic system, some liquids have advantages over others. Oil is a liquid often preferred as the working fluid. Oil helps to lubricate the various sliding parts, prevents rust, and is readily available. For practical purposes, oil does not change its volume in the hydraulic system when the pressure is changed.

Pressure and Force

The foundation of modern hydraulic powered systems was established when a scientist named Blaise Pascal discovered that pressure in a fluid acts equally in all directions. This concept is known as Pascal's Law. The application of Pascal's Law requires the understanding of the relationship between force and pressure.

Force may be defined as a push or pull exerted against the total area of a surface. It is expressed in pounds. Pressure is the amount of force on a unit area of the surface. That is, pressure is the force acting upon one square inch of a surface.

The relationship between pressure and force is expressed mathematically.

$$F = P \times A$$

where:

F = force in lbf
P = pressure in $lbf/in.^2$, (psi)
A = area in $in.^2$

Example 1:

In a hydraulic system, the oil pressure at the inlet to the cylinder is 1500 psi, and the area of the piston over which the oil pressure acts is two square inches. Calculate the force exerted on the piston.

Solution:

Since F = P x A, the force of the oil on the piston is calculated as follows.

$F = 1500 \text{ lbf/in.}^2 \times 2 \text{ in.}^2$
$= 3000 \text{ lbf}$

Example 2:

A hydraulic valve requires a force of 1848 lbf to be opened. The piston area is 3 square inches. How much pressure does the hydraulic fluid have to exert for the valve to move?

Solution:

Since F = P x A, then $P = \frac{F}{A}$.

$P = \frac{1848 \text{ lbf}}{3 \text{ in.}^2}$

$P = 616 \text{ lbf/in.}^2$

Hydraulic Operation

The operation of a typical hydraulic system is illustrated in Figure 8. Oil from a tank or reservoir flows through a pipe into a pump. Often a filter is provided on the pump suction to remove impurities from the oil. The pump, usually a gear-type, positive displacement pump, can be driven by an electric motor, air motor, gas or steam turbine, or an internal combustion engine. The pump increases the pressure of the oil. The actual pressure developed depends upon the design of the system.

Most hydraulic systems have some method of preventing overpressure. As seen in Figure 8, one method of pressure control involves returning hydraulic oil to the oil reservoir. The pressure control box shown on Figure 8 is usually a relief valve that provides a means of returning oil to the reservoir upon overpressurization.

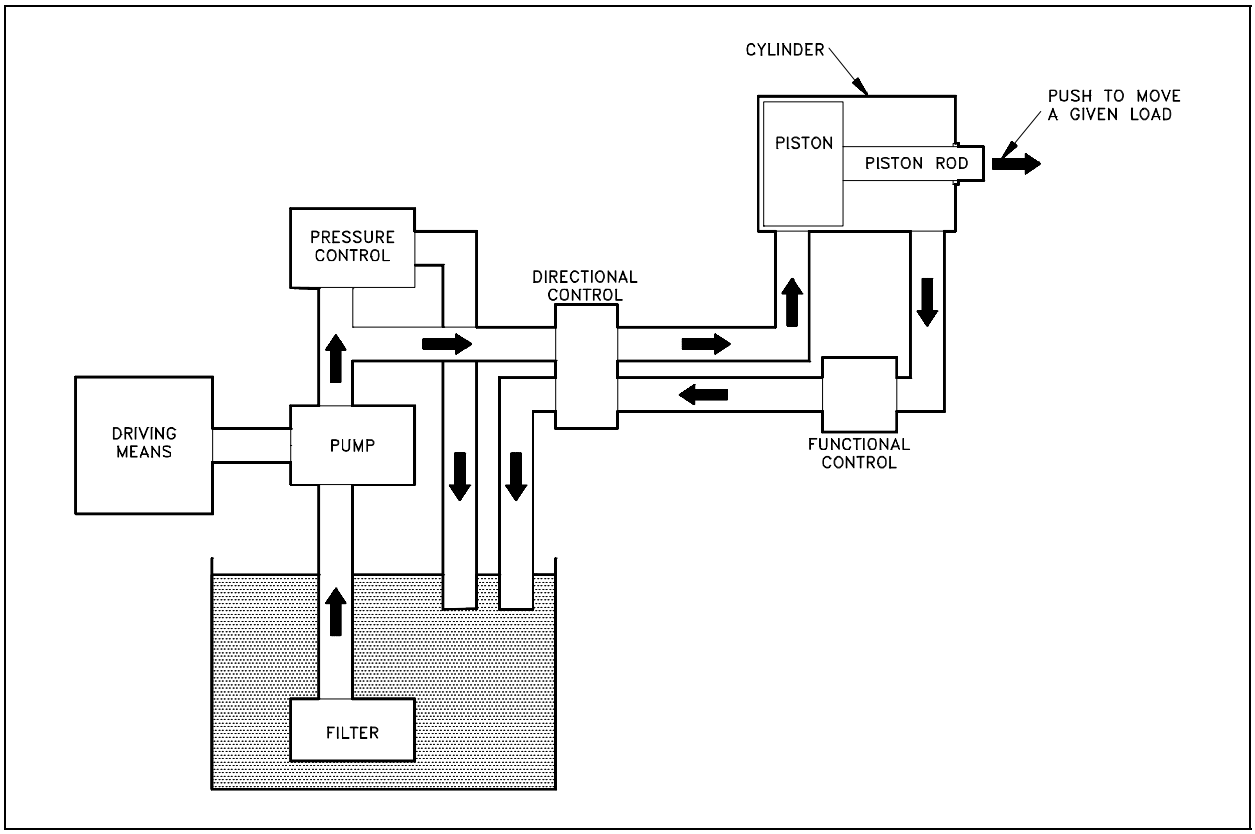

Figure 8 Basic Hydraulic System

The high pressure oil flows through a control valve (directional control). The control valve changes the direction of oil flow, depending upon the desired direction of the load. In Figure 8 the load can be moved to the left or to the right by changing the side of the piston to which the oil pressure is applied. The oil that enters the cylinder applies pressure over the area of the piston, developing a force on the piston rod. The force on the piston rod enables the movement of a load or device. The oil from the other side of the piston returns to a reservoir or tank.

Hazards

The hazards and precautions listed in the previous chapter on air compressors are applicable to hydraulic systems as well, because most of the hazards are associated with high pressure conditions. Any use of a pressurized medium can be dangerous. Hydraulic systems carry all the hazards of pressurized systems and special hazards that are related directly to the composition of the fluid used.

When using oil as a fluid in a high pressure hydraulic system, the possibility of fire or an explosion exists. A severe fire hazard is generated when a break in the high pressure piping occurs and the oil is vaporized into the atmosphere. Extra precautions against fire should be practiced in these areas.

If oil is pressurized by compressed air, an explosive hazard exists if the high pressure air comes into contact with the oil, because it may create a diesel effect and subsequent explosion. A carefully followed preventive maintenance plan is the best precaution against explosion.

Summary

The important information in this chapter is summarized below.

Hydraulics Summary

- The relationship between pressure and force in a hydraulic piston is expressed mathematically as:

  $F = P \times A$

  where:

  F = force
  P = pressure
  A = area

- Oil from a tank or reservoir flows through a pipe into a pump. The pump can be driven by a motor, turbine, or an engine. The pump increases the pressure of the oil.

  The high pressure oil flows in the piping through a control valve. The control valve changes the direction of the oil flow. A relief valve, set at a desired safe operating pressure, protects the system from an over-pressure condition. Oil entering the cylinder applies pressure to the piston, developing a force on the piston rod.

  The force on the piston rod enables the movement of a load or device. The oil from the other side of the piston returns to a reservoir or tank via a filter, which removes foreign particles.

BOILERS

Boilers are commonly used at large facilities to act as primary or backup steam sources. The source of heat that generates the steam varies, but the basic operation of the boiler is the same. This chapter will summarize the operation of a boiler.

EO 1.7 DESCRIBE the basic operation of a boiler.

EO 1.8 IDENTIFY the following components of a typical boiler:

a. Steam drum
b. Distribution header(s)
c. Combustion chamber
d. Downcomer
e. Risers

Introduction

The primary function of a boiler is to produce steam at a given pressure and temperature. To accomplish this, the boiler serves as a furnace where air is mixed with fuel in a controlled combustion process to release large quantities of heat. The pressure-tight construction of a boiler provides a means to absorb the heat from the combustion and transfer this heat to raise water to a temperature such that the steam produced is of sufficient temperature and quality (moisture content) for steam loads.

Boilers

Two distinct heat sources used for boilers are electric probes and burned fuel (oil, coal, etc.) This chapter will use fuel boilers to illustrate the typical design of boilers. Refer to Figure 9 during the following discussion.

The boiler has an enclosed space where the fuel combustion takes place, usually referred to as the furnace or combustion chamber. Air is supplied to combine with the fuel, resulting in combustion. The heat of combustion is absorbed by the water in the risers or circulating tubes. The density difference between hot and cold water is the driving force to circulate the water back to the steam drum. Eventually the water will absorb sufficient heat to produce steam.

Steam leaves the steam drum via a baffle, which causes any water droplets being carried by the steam to drop out and drain back to the steam drum. If superheated steam is required, the steam may then travel through a superheater. The hot combustion gasses from the furnace will heat the steam through the superheater's thin tube walls. The steam then goes to the steam supply system and the various steam loads.

Some boilers have economizers to improve cycle efficiency by preheating inlet feedwater to the boiler. The economizer uses heat from the boiler exhaust gasses to raise the temperature of the inlet feedwater.

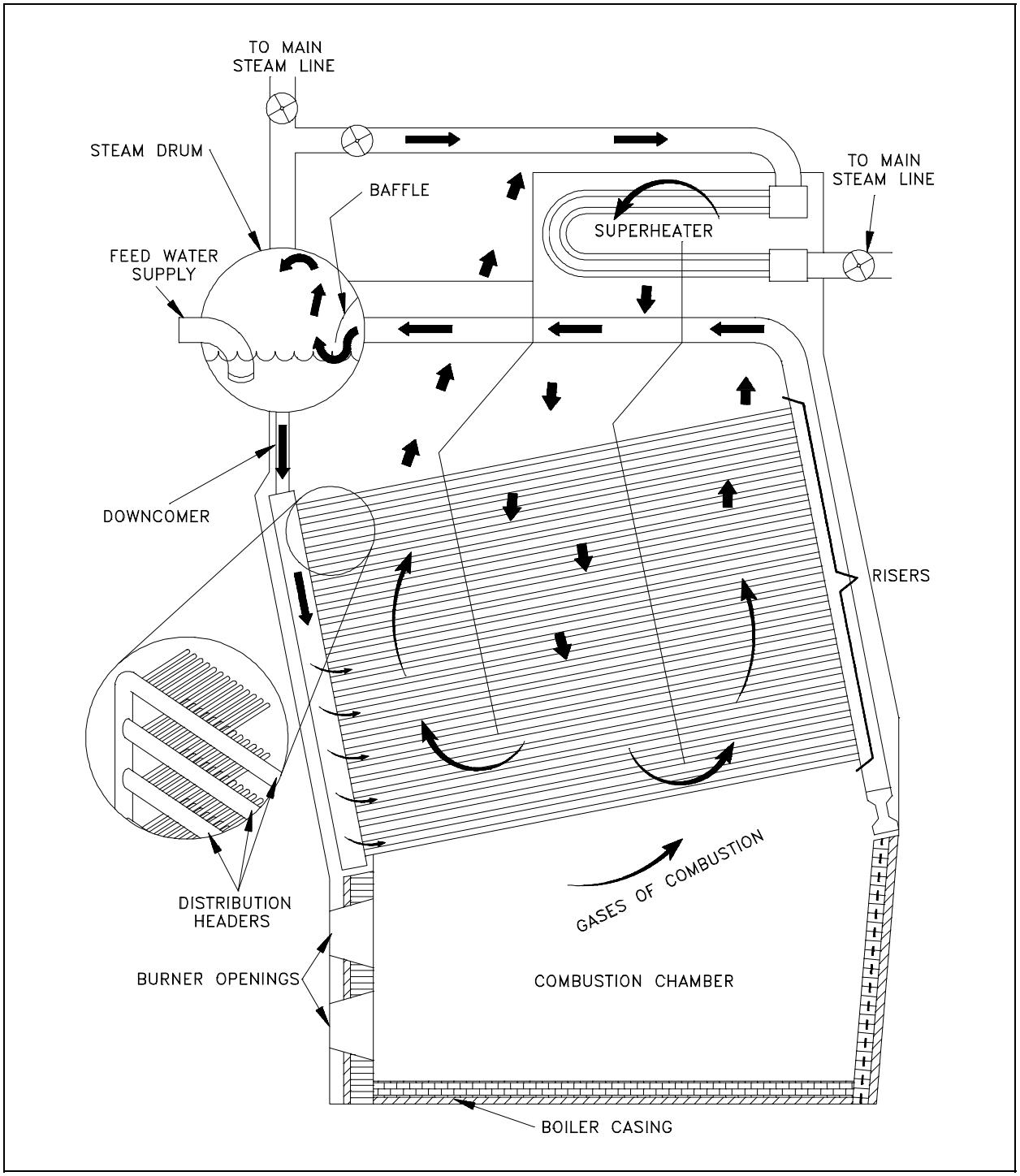

Figure 9 Typical Fuel Boiler

Fuel Boiler Components

Figure 9 illustrates a typical fuel boiler. Some of the components are explained below.

Steam drum - The steam drum separates the steam from the heated water. The water droplets fall to the bottom of the tank to be cycled again, and the steam leaves the drum and enters the steam system. Feedwater enters at the bottom of the drum to start the heating cycle.

Downcomers - Downcomers are the pipes in which the water from the steam drum travels in order to reach the bottom of the boiler where the water can enter the distribution headers.

Distribution headers - The distribution headers are large pipe headers that carry the water from the downcomers to the risers.

Risers - The piping or tubes that form the combustion chamber enclosure are called risers. Water and steam run through these to be heated. The term risers refers to the fact that the water flow direction is from the bottom to the top of the boiler. From the risers, the water and steam enter the steam drum and the cycle starts again.

Combustion chamber - Located at the bottom of a boiler, the combustion chamber is where the air and fuel mix and burn. It is lined with the risers.

Summary

The important information in this chapter is summarized below.

Boilers Summary

- Boilers are vessels that allow water in contained piping to be heated to steam by a heat source internal to the vessel. The water is heated to the boiling point. The resulting steam separates, and the water is heated again. Some boilers use the heat from combustion off-gasses to further heat the steam (superheat) and/or to preheat the feedwater.

- The following components were discussed:

  The steam drum is where the steam is separated from the heated water.

  Downcomers are the pipes in which the water from the steam drum travels to reach the bottom of the boiler.

  Distribution headers are large pipe headers that carry the water from the downcomers to the risers.

  Risers are the piping or tubes that form the combustion chamber enclosure. Water and steam run through the risers to be heated.

  The combustion chamber is located at the bottom of the boiler and is where the air and fuel mix and burn.

COOLING TOWERS

In an effort to lower costs and meet new environmental regulations, companies are developing new ways to do things. One of the developments which meets both cost decrease and environmental awareness is the cooling tower. This chapter will summarize the advantages of cooling towers and how they function.

EO 1.9 STATE the purpose of cooling towers.

EO 1.10 DESCRIBE the operation of the following types of cooling towers:

a. Forced draft
b. Natural convection

Purpose

Before the development of cooling towers, rivers, lakes, and cooling ponds were required to supply cooling. Through the development of the mechanical draft cooling tower, as little as one square foot of area is needed for every 1000 square feet required for a cooling pond or lake. Cooling towers minimize the thermal pollution of the natural water heat sinks and allow the reuse of circulating water. An example of the manner in which a cooling tower can fit into a system is shown in Figure 10.

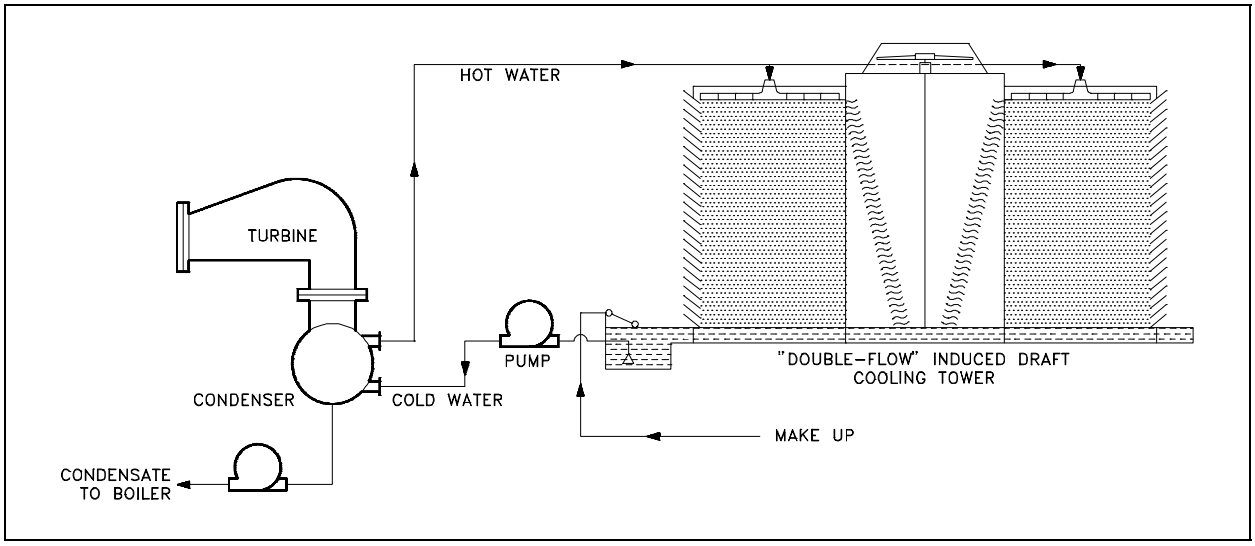

Figure 10 Cooling System Containing Cooling Tower

The cooling of the water in a cooling tower is accomplished by the direct contact of water and air. This cooling effect is provided primarily by an exchange of latent heat of vaporization resulting from evaporation of a small amount of water and by a transfer of sensible heat, which raises the temperature of the air. The heat transferred from the water to the air is dissipated to the atmosphere.

Induced Draft Cooling Towers

Induced draft cooling towers, illustrated in Figure 11, are constructed such that the incoming circulating water is dispersed throughout the cooling tower via a spray header. The spray is directed down over baffles that are designed to maximize the contact between water and air. The air is drawn through the baffled area by large circulating fans and causes the evaporation and the cooling of the water.

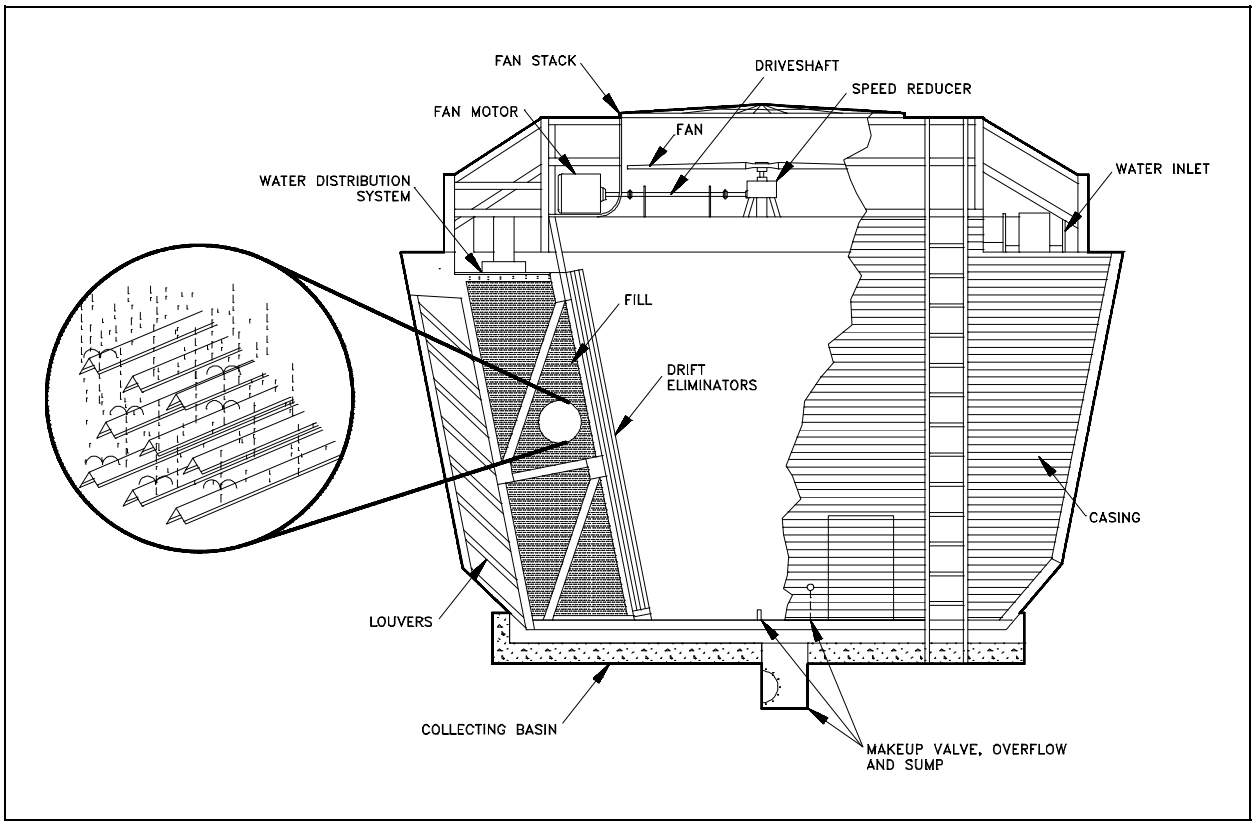

Figure 11 Induced Draft Cooling Tower

The nomenclature for induced draft cooling towers, including some items not illustrated in Figure 11 is summarized below.

Casing - The casing encloses the walls of the cooling tower, exclusive of fan deck and louvers.

Collecting basin - The collecting basin is a receptacle beneath the cooling tower for collecting the water cooled by the cooling tower. It can be made of concrete, wood, metal, or an alternative material. Certain necessary accessories are required such as sump, strainers, overflow, drain, and a makeup system.

Drift eliminators - The drift eliminators are parallel blades of PVC, wood, metal, or an alternative material arranged on the air discharge side of the fill to remove entrained water droplets from the leaving air stream.

Driver - The driver is a device that supplies power to turn the fan. It is usually an electric motor, but turbines and internal combustion engines are occasionally used.

Drive shaft - The drive shaft is a device, including couplings, which transmits power from the driver to the speed reducer.

Fan - The fan is a device used to induce air flow through the cooling tower.

Fan deck - The fan deck is a horizontal surface enclosing the top of the cooling tower above the plenum that serves as a working platform for inspection and maintenance.

Fan stack - The fan stack is a cylinder enclosing the fan, usually with an eased inlet and an expanding discharge for increased fan efficiency.

Fill - The fill is PVC, wood, metal, or an alternative material that provides extended water surface exposure for evaporative heat transfer.

Intake louvers - The intake louvers are an arrangement of horizontal blades at the air inlets that prevent escape of falling water while allowing the entry of air.

Makeup valve - The makeup valve is a valve that introduces fresh water into the collection basin to maintain the desired collecting basin water level.

Overflow - The overflow is a drain that prevents the collecting basin from overflowing.

Partition - The partition is a baffle within a multicell cooling tower that is used to prevent air and/or water flow between adjacent cells.

Plenum - The plenum is the internal cooling tower area between the drift eliminators and the fans.

Speed reducer - The speed reducer is a right-angle gear box that transmits power to the fan while reducing the driver speed to that required for optimal fan performance.

Sump - The sump is a depressed portion of the collecting basin from which cold water is drawn to be returned to the connected system. The sump usually contains strainer screens, antivortex devices, and a drain or cleanout connection.

Distribution system - The distribution system is that portion of a cooling tower that distributes water over the fill area. It usually consists of one or more flanged inlets, flow control valves, internal headers, distribution basins, spray branches, metering orifices, and other related components.

Forced Draft Cooling Towers

Forced draft cooling towers are very similar to induced draft cooling towers. The primary difference is that the air is blown in at the bottom of the tower and exits at the top. Forced draft cooling towers are the forerunner to induced draft cooling towers. Water distribution problems and recirculation difficulties discourage the use of forced draft cooling towers.

Natural Convection Cooling Towers

Natural convection cooling towers, illustrated in Figure 12, use the principle of convective flow to provide air circulation. As the air inside the tower is heated, it rises through the tower. This process draws more air in, creating a natural air flow to provide cooling of the water. The basin at the bottom of the tower is open to the atmosphere. The cooler, more dense air outside the

tower will flow in at the bottom and contribute to the air circulation within the tower. The air circulation will be self perpetuating due to the density difference between the warmer air inside and the cooler air outside.

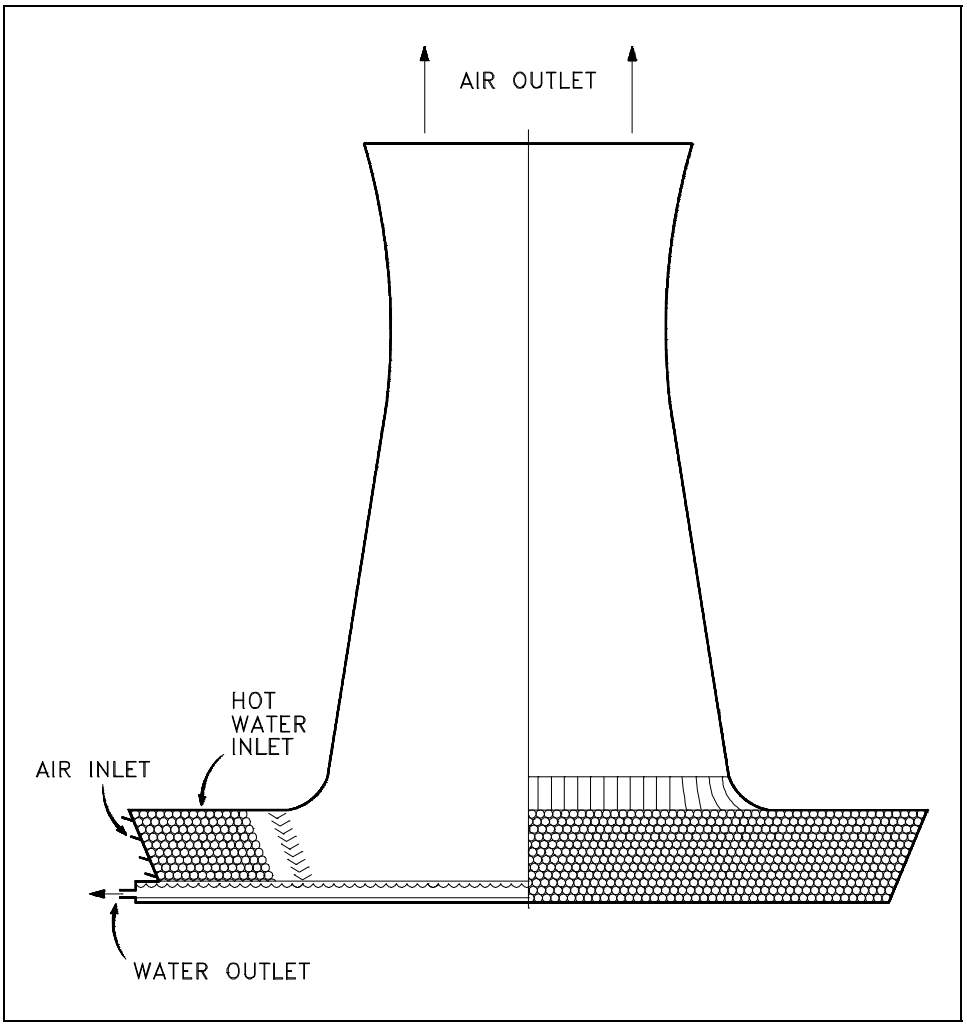

Figure 12 Natural Convection Cooling Tower

The incoming water is sprayed around the circumference of the tower and cascades to the bottom. The natural convection cooling towers are much larger than the forced draft cooling towers and cost much more to construct. Because of space considerations and cost, natural convection cooling towers are built less frequently than other types.

Summary

The important information in this chapter is summarized below.

Cooling Towers Summary

- The cooling tower removes heat from water used in cooling systems within the plant. The heat is released to the air rather than to a lake or stream. This allows facilities to locate in areas with less water available because the cooled water can be recycled. It also aids environmental efforts by not contributing to thermal pollution.
- Induced draft cooling towers use fans to create a draft that pulls air through the cooling tower fill. Because the water to be cooled is distributed such that it cascades over the baffles, the air blows through the water, cooling it.
- Forced draft cooling towers blow air in at the bottom of the tower. The air exits at the top of the tower. Water distribution and recirculation difficulties limit their use.
- Natural convection cooling towers function on the basic principle that hot air rises. As the air inside the tower is heated, it rises through the tower. This process draws more air in, creating a natural air flow to provide cooling of the water.

DEMINERALIZERS

The cost of corrosion and radioactive contamination caused by poor water quality in nuclear facilities is enormous. Demineralizers are an intricate part of water quality control. The chemical theory of demineralizers is detailed in the Chemistry Fundamentals Handbook. This chapter will address the mechanics of how demineralizers operate.

EO 1.11 STATE the purpose of a demineralizer.

Purpose of Demineralizers

Dissolved impurities in power plant fluid systems generate corrosion problems and decrease efficiency due to fouled heat transfer surfaces. Demineralization of the water is one of the most practical and common methods available to remove these dissolved impurities.

In the plant, demineralizers (also called ion-exchangers) are used to hold ion exchange resins and transport water through them. Ion exchangers are generally classified into two groups: single-bed ion exchangers and mixed-bed ion exchangers.

Demineralizers

A demineralizer is basically a cylindrical tank with connections at the top for water inlet and resin addition, and connections at the bottom for the water outlet. The resin can usually be changed through a connection at the bottom of the tank. The resin beads are kept in the demineralizer by upper and lower retention elements, which are strainers with a mesh size smaller then the resin beads. The water to be purified enters the top at a set flow rate and flows down through the resin beads, where the flow path causes a physical filter effect as well as a chemical ion exchange.

Single-Bed Demineralizers

A single-bed demineralizer contains either cation or anion resin beads. In most cases, there are two, single-bed ion exchangers in series; the first is a cation bed and the second is an anion bed. Impurities in plant water are replaced with hydrogen ions in the cation bed and hydroxyl ions in the anion bed. The hydrogen ions and the hydroxyl ions then combine to form pure water. The Chemistry Handbook, Module 4, Principles of Water Treatment, addresses the chemistry of demineralizers in more detail.

Figure 13 illustrates a single-bed demineralizer. When in use, water flows in through the inlet to a distributor at the top of the tank. The water flows down through the resin bed and exits out through the outlet. A support screen at the bottom prevents the resin from being forced out of the demineralizer tank.

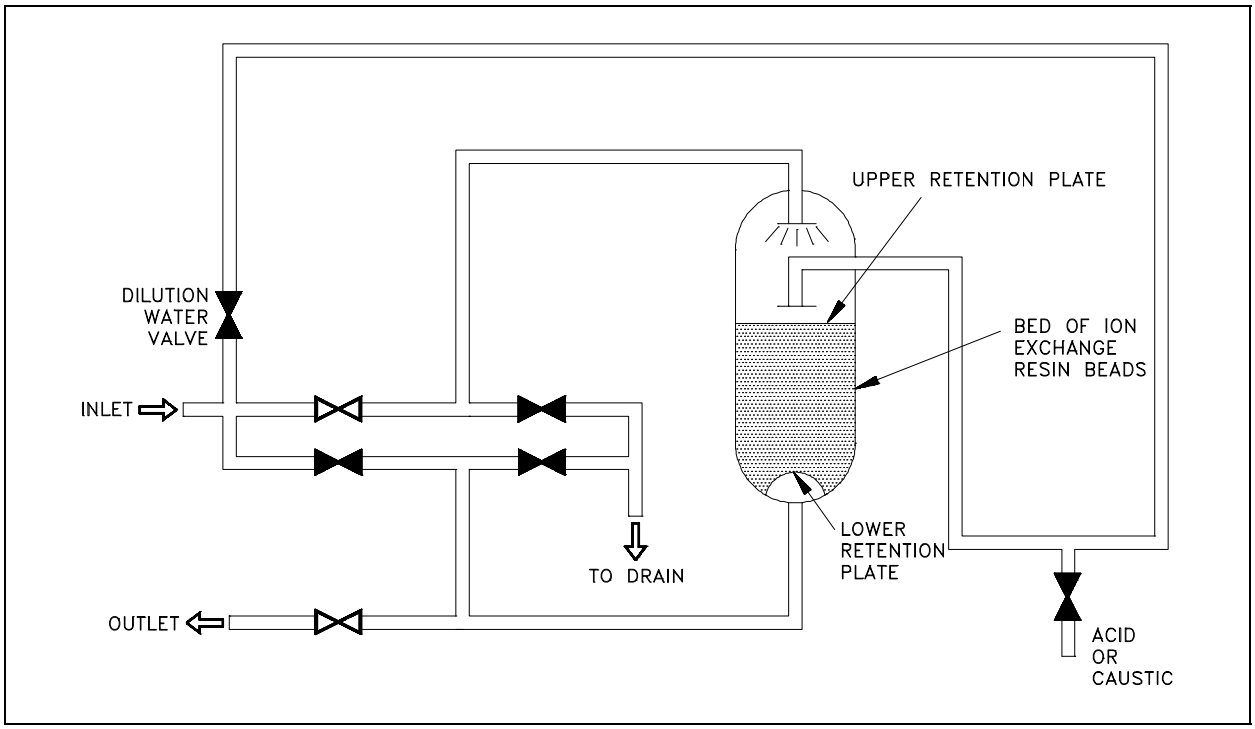

Figure 13 Single-Bed Demineralizer

Single-Bed Regeneration

The regeneration of a single-bed ion exchanger is a three-step process. The first step is a backwash, in which water is pumped into the bottom of the ion exchanger and up through the resin. This fluffs the resin and washes out any entrained particles. The backwash water goes out through the normal inlet distributor piping at the top of the tank, but the valves are set to direct the stream to a drain so that the backwashed particles can be pumped to a container for waste disposal.

The second step is the actual regeneration step, which uses an acid solution for cation units and caustic solution for anion units. The concentrated acid or caustic is diluted to approximately 10% with water by opening the dilution water valve, and is then introduced through a distribution system immediately above the resin bed. The regenerating solution flows through the resin and out the bottom of the tank to the waste drain.

The final step is a rinsing process, which removes any excess regenerating solution. Water is pumped into the top of the tank, flows down through the resin bed and out at the bottom drain.

To return the ion exchanger to service, the drain valve is closed, the outlet valve is opened, and the ion exchanger is ready for service.

Single-bed demineralizers are usually regenerated "in place." The resins are not pumped out to another location for regeneration. The regeneration process is the same for cation beds and for anion beds; only the regenerating solution is different. It is important to realize that if the ion exchanger has been exposed to radioactive materials, the backwash, regeneration, and rinse solutions may be highly radioactive and must be treated as a radioactive waste.

Mixed-Bed Demineralizer

A mixed-bed demineralizer is a demineralizer in which the cation and anion resin beads are mixed together. In effect, it is equivalent to a number of two-step demineralizers in series. In a mixed-bed demineralizer, more impurities are replaced by hydrogen and hydroxyl ions, and the water that is produced is extremely pure. The conductivity of this water can often be less than 0.06 micromhos per centimeter.

Mixed-Bed Regeneration

The mixed-bed demineralizer shown in Figure 14 is designed to be regenerated in place, but the process is more complicated than the regeneration of a single-bed ion exchanger. The steps in the regeneration are shown in Figure 14.

Figure 14a shows the mixed-bed ion exchanger in the operating, or on-line mode. Water enters through a distribution header at the top and exits through the line at the bottom of the vessel. Regeneration causes the effluent water to increase in electrical conductivity.

The first regeneration step is backwash, as shown in Figure 14b. As in a single-bed unit, backwash water enters the vessel at the bottom and exits through the top to a drain. In addition to washing out entrained particles, the backwash water in a mixed-bed unit must also separate the resins into cation and anion beds. The anion resin has a lower specific gravity than the cation resin; therefore, as the water flows through the bed, the lighter anion resin beads float upward to the top. Thus, the mixed-bed becomes a split bed. The separation line between the anion bed at the top and the cation bed at the bottom is called the resin interface. Some resins can be separated only when they are in the depleted state; other resins separate in either the depleted form or the regenerated form.

The actual regeneration step is shown in Figure 14c. Dilution water is mixed with caustic solution and introduced at the top of the vessel, just above the anion bed. At the same time, dilution water is mixed with acid and introduced at the bottom of the vessel, below the cation bed. The flow rate of the caustic solution down to the resin interface is the same as the flow rate of the acid solution up to the resin interface. Both solutions are removed at the interface and dumped to a drain.

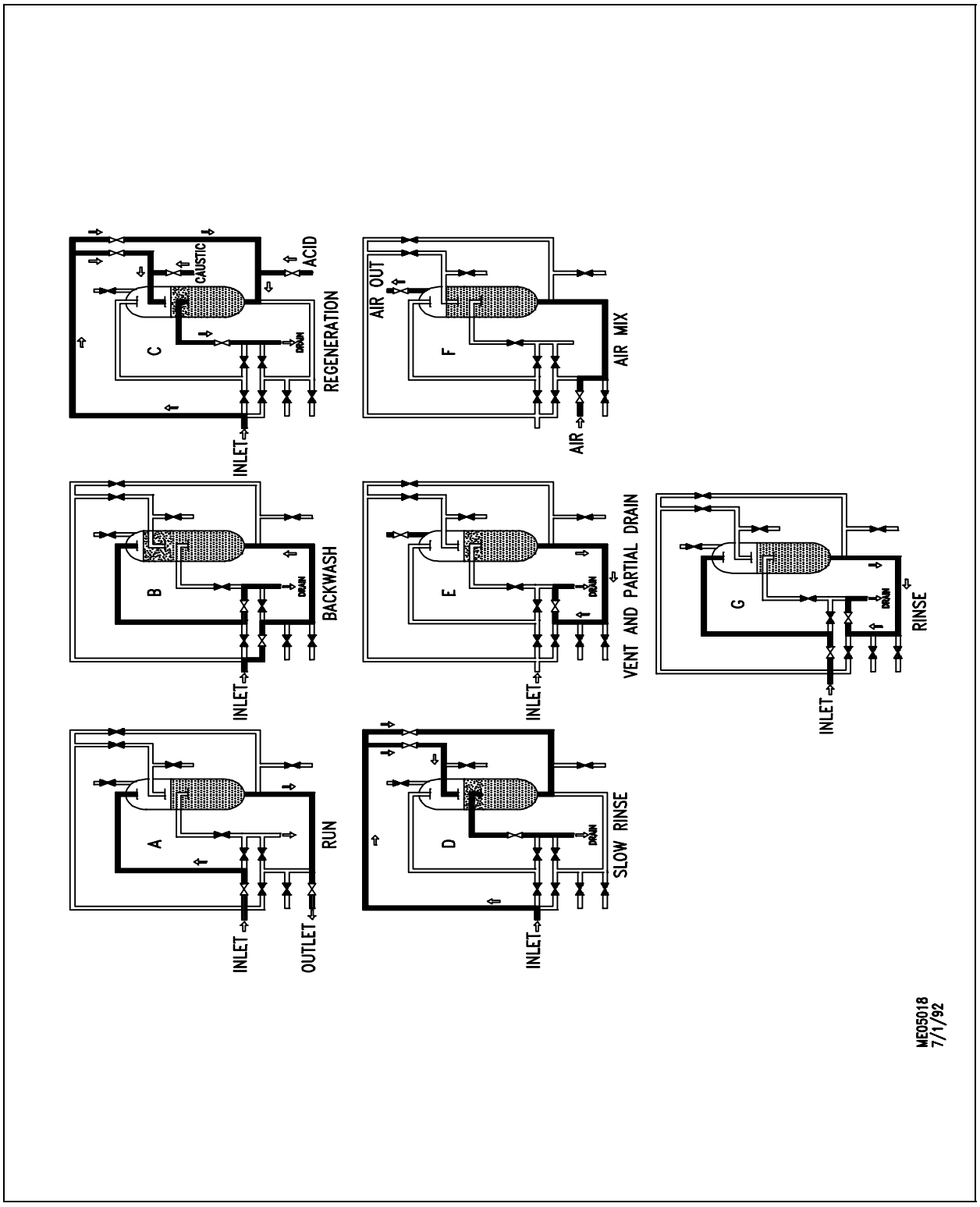

Figure 14 Regeneration of a Mixed-Bed Demineralizer

During the regeneration step, it is important to maintain the cation and anion resins at their proper volume. If this is not done, the resin interface will not occur at the proper place in the vessel, and some resin will be exposed to the wrong regenerating solution. It is also important to realize that if the ion exchanger has been involved with radioactive materials, both the backwash and the regenerating solutions may be highly radioactive and must be treated as liquid radioactive waste.

The next step is the slow rinse step, shown in Figure 14d, in which the flow of dilution water is continued, but the caustic and acid supplies are cut off. During this two-direction rinse, the last of the regenerating solutions are flushed out of the two beds and into the interface drain. Rinsing from two directions at equal flow rates keeps the caustic solution from flowing down into the cation resin and depleting it.

In the vent and partial drain step, illustrated in Figure 14e, the drain valve is opened, and some of the water is drained out of the vessel so that there will be space for the air that is needed to re-mix the resins. In the air mix step, (Figure 14f) air is usually supplied by a blower, which forces air in through the line entering the bottom of the ion exchanger. The air mixes the resin beads and then leaves through the vent in the top of the vessel. When the resin is mixed, it is dropped into position by slowly draining the water out of the interface drain while the air mix continues.

In the final rinse step, shown in Figure 14g, the air is turned off and the vessel is refilled with water that is pumped in through the top. The resin is rinsed by running water through the vessel from top to bottom and out the drain, until a low conductivity reading indicates that the ion exchanger is ready to return to service.

External Regeneration

Some mixed-bed demineralizers are designed to be regenerated externally, with the resins being removed from the vessel, regenerated, and then replaced. With this type of demineralizer, the first step is to sluice the mixed bed with water (sometimes assisted by air pressure) to a cation tank in a regeneration facility. The resins are backwashed in this tank to remove suspended solids and to separate the resins. The anion resins are then sluiced to an anion tank. The two batches of separated resins are regenerated by the same techniques used for single-bed ion exchangers. They are then sluiced into a holding tank where air is used to remix them. The mixed, regenerated, resins are then sluiced back to the demineralizer.

External regeneration is typically used for groups of condensate demineralizers. Having one central regeneration facility reduces the complexity and cost of installing several demineralizers. External regeneration also allows keeping a spare bed of resins in a holding tank. Then, when a demineralizer needs to be regenerated, it is out of service only for the time required to sluice out the depleted bed and sluice a fresh bed in from the holding tank. A central regeneration facility may also include an ultrasonic cleaner that can remove the tightly adherent coating of dirt or iron oxide that often forms on resin beads. This ultrasonic cleaning reduces the need for chemical regeneration.

Summary

The important information in this chapter is summarized below.

Demineralizers Summary

- Demineralization of water is one of the most practical and common methods used to remove dissolved contaminates. Dissolved impurities in power plant fluid systems can generate corrosion problems and decrease efficiency due to fouled heat transfer surfaces. Demineralizers (also called ion-exchangers) are used to hold ion exchange resins and transport water through them. Ion exchangers are generally classified into two groups: single-bed ion exchangers and mixed-bed ion exchangers.

- A demineralizer is basically a cylindrical tank with connections at the top for water inlet and resin addition, and connections at the bottom for the water outlet. The resin can usually be changed out through a connection at the bottom of the tank. The resin beads are kept in the demineralizer by upper and lower retention elements, which are strainers with a mesh size smaller then the resin beads.

- The water to be purified enters the top at a set flow rate, flows down through the resin beads where the flow path causes a physical filter effect as well as a chemical ion exchange. The chemistry of the resin exchange is explained in detail in the Chemistry Fundamentals Handbook.

- There are two types of demineralizers, single-bed and mixed-bed. Single-bed demineralizers have resin of either cation or anion exchange sites. Mixed-bed demineralizers contain both anion and cation resin.

- All demineralizers will eventually be exhausted from use. To regenerate the resin and increase the demineralizer's efficiency, the demineralizers are regenerated. The regeneration process is slightly different for a mixed-bed demineralizer compared to the single-bed demineralizer. Both methods were explained in this chapter.

PRESSURIZERS

Pressurizers are used for reactor system pressure control. The pressurizer is the component that allows a water system, such as the reactor coolant system in a PWR facility, to maintain high temperatures without boiling. The function of pressurizers is discussed in this chapter.

EO 1.12 STATE the four purposes of a pressurizer.

EO 1.13 DEFINE the following terms attributable to a dynamic pressurizer system:

a. Spray nozzle
b. Insurge
c. Outsurge
d. Surge volume

Introduction

There are two types of pressurizers: static and dynamic. A static pressurizer is a partially filled tank with a required amount of gas pressure trapped in the void area. A dynamic pressurizer is a tank in which its saturated environment is controlled through use of heaters (to control temperature) and sprays (to control pressure).

This chapter focuses on the dynamic pressurizer. A dynamic pressurizer utilizes a controlled pressure containment to keep high temperature fluids from boiling, even when the system undergoes abnormal fluctuations.

Before discussing the purpose, construction, and operation of a pressurizer, some preliminary information about fluids will prove helpful.

The evaporation process is one in which a liquid is converted into a vapor at temperatures below the boiling point. All the molecules in the liquid are continuously in motion. The molecules that move most quickly possess the greatest amount of energy. This energy occasionally escapes from the surface of the liquid and moves into the atmosphere. When molecules move into the atmosphere, the molecules are in the gaseous, or vapor, state.

Liquids at a high temperature have more molecules escaping to the vapor state, because the molecules can escape only at higher speeds. If the liquid is in a closed container, the space above the liquid becomes saturated with vapor molecules, although some of the molecules return to the liquid state as they slow down. The return of a vapor to a liquid state is called condensation. When the amount of molecules that condense is equal to the amount of molecules that evaporate, there is a dynamic equilibrium between the liquid and the vapor.

Pressure exerted on the surface of a liquid by a vapor is called vapor pressure. Vapor pressure increases with the temperature of the liquid until it reaches saturation pressure, at which time the liquid boils. When a liquid evaporates, it loses its most energetic molecules, and the average energy per molecule in the system is lowered. This causes a reduction in the temperature of the liquid.

Boiling is the activity observed in a liquid when it changes from the liquid phase to the vapor phase through the addition of heat. The term saturated liquid is used for a liquid that exists at its boiling point. Water at 212°F and standard atmospheric pressure is an example of a saturated liquid.

Saturated steam is steam at the same temperature and pressure as the water from which it was formed. It is water, in the form of a saturated liquid, to which the latent heat of vaporization has been added. When heat is added to a saturated steam that is not in contact with liquid, its temperature is increased and the steam is superheated. The temperature of superheated steam, expressed as degrees above saturation, is called degrees of superheat.

General Description

The pressurizer provides a point in the reactor system where liquid and vapor can be maintained in equilibrium under saturated conditions, for control purposes. Although designs differ from facility to facility, a typical pressurizer is designed for a maximum of about 2500 psi and 680°F.

Dynamic Pressurizers

A dynamic pressurizer serves to:

- maintain a system's pressure above its saturation point,
- provide a means of controlling system fluid expansion and contraction,
- provide a means of controlling a system's pressure, and
- provide a means of removing dissolved gasses from the system by venting the vapor space of the pressurizer.

Construction

A dynamic pressurizer is constructed from a tank equipped with a heat source such as electric heaters at its base, a source of cool water, and a spray nozzle. A *spray nozzle* is a device located in the top of the pressurizer that is used to atomize the incoming water.

A dynamic pressurizer must be connected in the system to allow a differential pressure to exist across it. The bottom connection, also called the surge line, is the lower of the two pressure lines. The top connection, referred to as the spray line, is the higher pressure line. Differential pressure is obtained by connecting the pressurizer to the suction and discharge sides of the pump servicing the particular system. Specifically, the surge (bottom connection) is connected to the pump's suction side; the spray line (top connection) is connected to the pump's discharge side. A basic pressurizer is illustrated in Figure 15.

The hemispherical top and bottom heads are usually constructed of carbon steel, with austenitic stainless steel cladding on all surfaces exposed to the reactor system water.

The pressurizer can be activated in two ways. Partially filling the pressurizer with system water is the first. After the water reaches a predetermined level, the heaters are engaged to increase water temperature. When the water reaches saturation temperature, it begins to boil. Boiling water fills the void above the water level, creating a saturated environment of water and steam. The other method involves filling the pressurizer completely, heating the water to the desired temperature, then partially draining the water and steam mixture to create a steam void at the top of the vessel.

Water temperature determines the amount of pressure developed in the steam space, and the greater the amount of time the heaters are engaged, the hotter the environment becomes. The hotter the environment, the greater the amount of pressure.

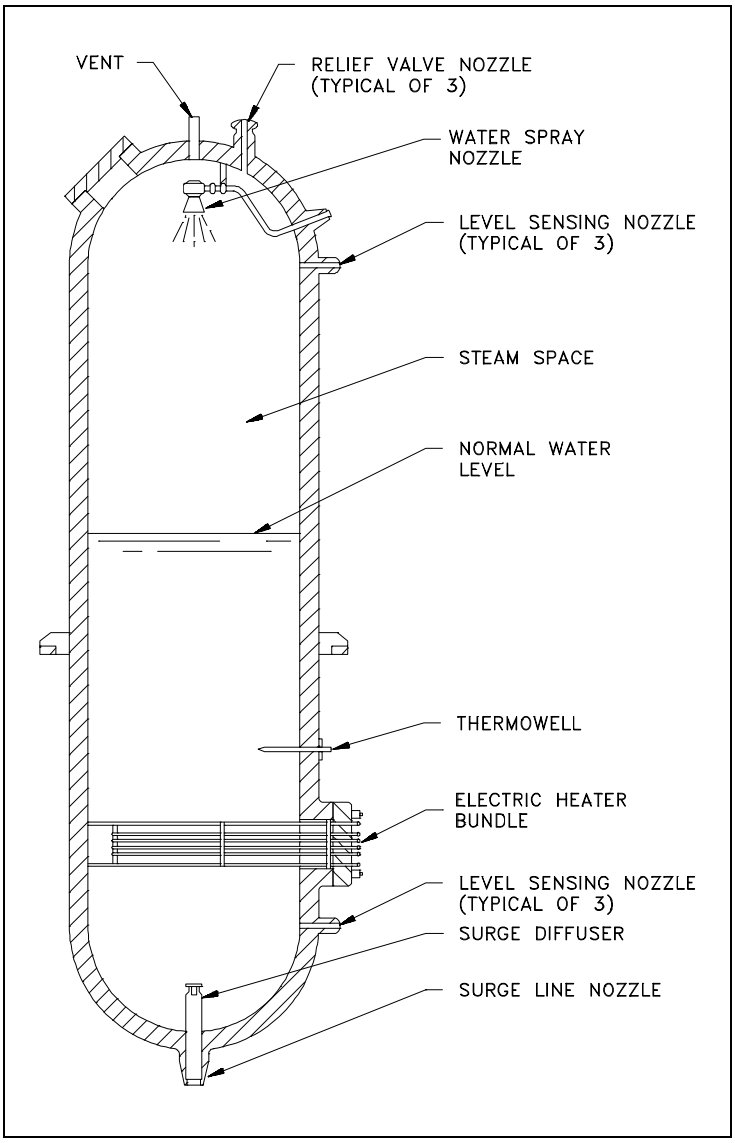

Figure 15 Basic Pressurizer

Installing a control valve in the spray line makes it possible to admit cooler water from the top of the pressurizer through the spray nozzle. Adding cooler water condenses the steam bubble, lowers the existing water temperature, and reduces the amount of system pressure.

Operation

The level of water within a pressurizer is directly dependant upon the temperature, and thus the density, of the water in the system to which the pressurizer is connected. An increase in system temperature causes the density of the water to decrease. This decreased density causes the water to expand, causing the level of water to increase in the vessel. The increased level of water in a pressurizer is referred to as an *insurge*. An insurge compresses the vapor space, which in turn causes the system pressure to rise. This results in slightly superheated steam in contact with the subcooled pressurizer liquid. The superheated steam transfers heat to the liquid and to the pressurizer walls. This re-establishes and maintains the saturated condition.

A decrease in system temperature causes the density to increase which causes the system water volume to contract. The contraction (drop) in pressurizer water level and increase in vapor space is referred to as an *outsurge*. The increase in vapor space causes the pressure to drop, flashing the heated water volume and creating more steam. The increased amount of steam re-establishes the saturated state. Flashing continues until the decrease in water level ceases and saturated conditions are restored at a somewhat lower pressure.

In each case, the final conditions place the pressurizer level at a new value. The system pressure remains at approximately its previous value, with relatively small pressure variations during the level change, provided that the level changes are not too extreme.

In actual application, relying on saturation to handle all variations in pressure is not practical. In conditions where the system water is surging into the pressurizer faster than the pressurizer can accommodate for example, additional control is obtained by activating the spray. This spray causes the steam to condense more rapidly, thereby controlling the magnitude of the pressure rise.

When a large outsurge occurs, the level can drop rapidly and the water cannot flash to steam fast enough. This results in a pressure drop. The installed heaters add energy to the water and cause it to flash to steam faster, thereby reducing the pressure drop. The heaters can also be left on to re-establish the original saturation temperature and pressure. In certain designs, pressurizer heaters are energized continuously to make up for heat losses to the environment.

The pressurizer's heater and spray capabilities are designed to compensate for the expected surge volume. The *surge volume* is the volume that accommodates the expansion and contraction of the system, and is designed to be typical of normal pressurizer performance. Plant transients may result in larger than normal insurges and outsurges. When the surge volume is exceeded, the pressurizer may fail to maintain pressure within normal operating pressures.

Pressurizer operation, including spray and heater operation, is usually automatically controlled. Monitoring is required in the event the control features fail, because the effect on the system could be disastrous without operator action.

Summary

The important information in this chapter is summarized below.

Pressurizer Summary

- Two types of pressurizers -- static and dynamic
- Purposes of a pressurizer:

  Maintains system pressure above saturation

  Provides a surge volume for system expansion and contraction

  Provides a means of controlling system pressure

  Provides a means of removing dissolved gases

- A spray nozzle is a device located in the top of the pressurizer, used to atomize incoming water to increase the effects of spraying water into the top of the pressurizer to reduce pressure by condensing steam.
- Insurge is the volume absorbed within the pressurizer during a level increase to compensate for a rise in the system's temperature.
- Outsurge is the volume released from the pressurizer during a level decrease to compensate for a reduction in the system's temperature.
- The surge volume is the volume of water that accommodates the expansion and contraction of the system, and is designed to be typical of normal pressurizer performance.

STEAM TRAPS

Steam traps are installed in steam lines to drain condensate from the lines without allowing the escape of steam. There are many designs of steam traps for high and low pressure use.

EO 1.14 STATE the purpose and general operation of a steam trap.

EO 1.15 IDENTIFY the following types of steam traps:

a. Ball float steam trap
b. Bellow steam trap
c. Bucket steam trap
d. Impulse steam trap

General Operation

In general, a steam trap consists of a valve and a device or arrangement that causes the valve to open and close as necessary to drain the condensate from piping without allowing the escape of steam. Steam traps are installed at low points in the system or machinery to be drained. Some types of steam traps that are used in DOE facilities are described in this chapter.

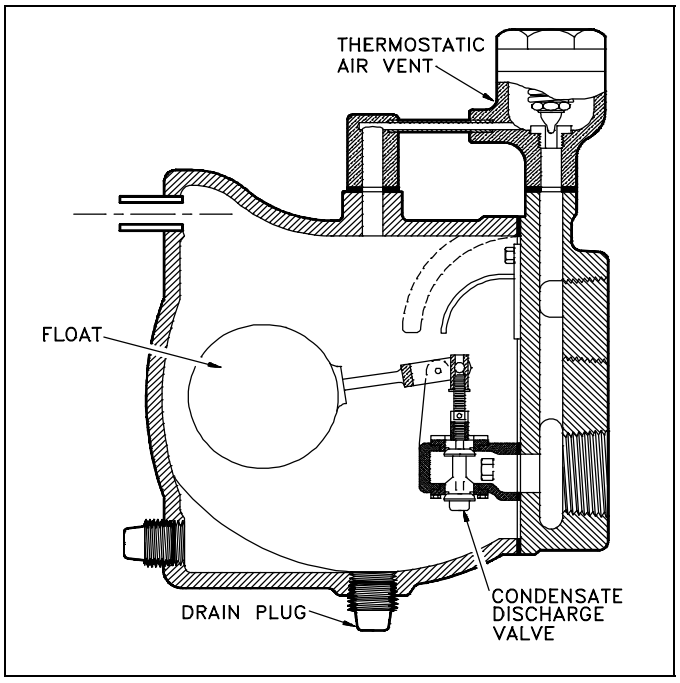

Figure 16 Ball Float Steam Trap

Ball Float Steam Trap

A ball float steam trap is illustrated in Figure 16. The valve of this trap is connected to the float in such a way that the valve opens when the float rises. When the trap is in operation, the steam and any water that may be mixed with it flows into the float chamber. The water, being heavier than the steam, falls to the bottom of the trap, causing the water level to rise. As the water level rises, it lifts the float; thus lifting the valve plug and opening the valve. The condensate drains out and the float moves down to a lower position, closing the valve before the condensate level gets low enough to allow steam to escape. The condensate that passes out of the trap is returned to the feed system.

Bucket Steam Trap

A bucket steam trap is illustrated in Figure 17. As condensate enters the trap body, the bucket floats. The valve is connected to the bucket in such a way that the valve closes as the bucket rises. As condensate continues to flow into the trap body, the valve remains closed until the bucket is full. When the bucket is full, it sinks and thus opens the valve. The valve remains open until enough condensate has passed out to allow the bucket to float, and closing the valve.

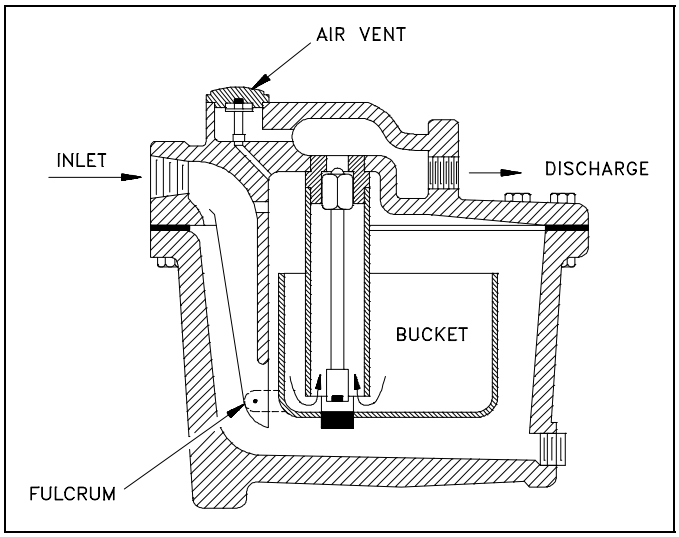

Figure 17 Bucket Steam Trap

Thermostatic Steam Traps

There are several kinds of thermostatic steam traps in use. In general, these traps are more compact and have fewer moving parts than most mechanical steam traps.

Bellows-Type Steam Trap

A bellows-type steam trap is illustrated in Figure 18. The operation of this trap is controlled by the expansion of the vapor of a volatile liquid, which is enclosed in a bellows-type element. Steam enters the trap body and heats the volatile liquid in the sealed bellows, causing expansion of the bellows.

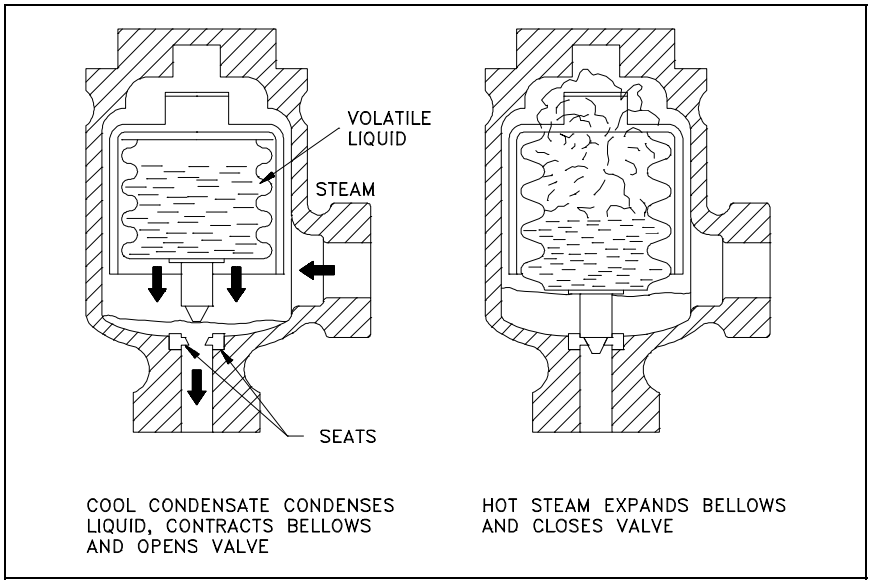
VOLATILE LIQUID
STEAM
SEATS
COOL CONDENSATE CONDENSES LIQUID, CONTRACTS BELLOWS AND OPENS VALVE
HOT STEAM EXPANDS BELLOWS AND CLOSES VALVE

Figure 18 Bellows-Type Steam Trap

The valve is attached to the bellows in such a way that the valve closes when the bellows expands. The valve remains closed, trapping steam in the valve body. As the steam cools and condenses, the bellows cools and contracts, thereby opening the valve and allowing the condensate to drain.

Impulse Steam Trap

Impulse steam traps, illustrated in Figure 19, pass steam and condensate through a strainer before entering the trap. A circular baffle keeps the entering steam and condensate from impinging on the cylinder or on the disk. The impulse type of steam trap is dependent on the principle that hot water under pressure tends to flash into steam when the pressure is reduced.

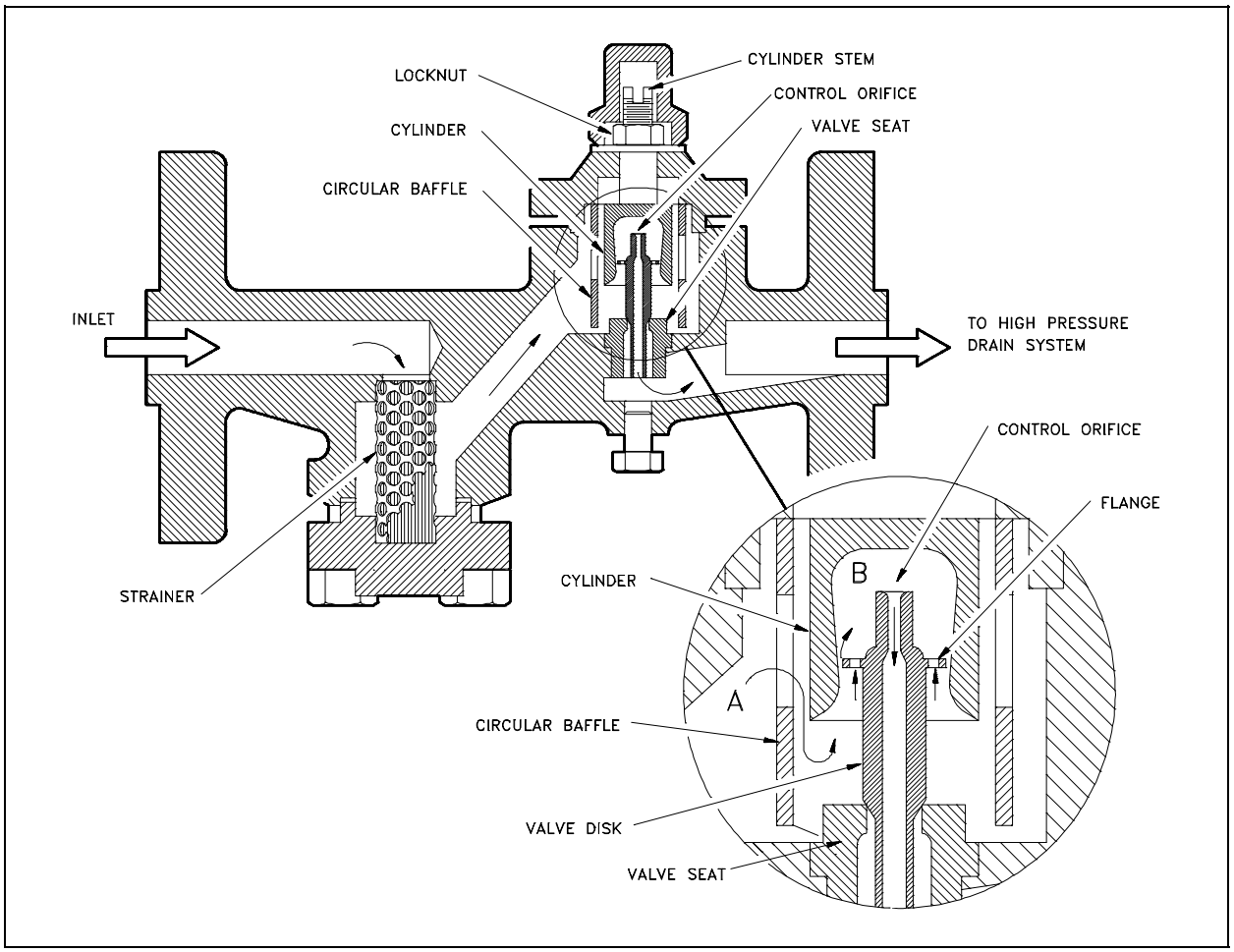

Figure 19 Impulse Steam Trap

The only moving part in the steam trap is the disk. A flange near the top of the disk acts as a piston. As demonstrated in Figure 19, the working surface above the flange is larger than the working surface below the flange.

A control orifice runs through the disk from top to bottom, which is considerably smaller at the top than at the bottom. The bottom part of the disk extends through and beyond the orifice in the seat. The upper part of the disk (including the flange) is inside a cylinder. The cylinder tapers inward, so the amount of clearance between the flange and the cylinder varies according to the position of the valve. When the valve is open, the clearance is greater than when the valve is closed.

When the trap is first placed in service, pressure from the inlet (chamber A) acts against the underside of the flange and lifts the disk off the valve seat. Condensate is thus allowed to pass out through the orifice in the seat; and, at the same time, a small amount of condensate (called control flow) flows up past the flange and into chamber B. The control flow discharges through the control orifice, into the outlet side of the trap, and the pressure in chamber B remains lower than the pressure in chamber A.

As the line warms up, the temperature of the condensate flowing through the trap increases. The reverse taper of the cylinder varies the amount of flow around the flange until a balanced position is reached in which the total force exerted above the flange is equal to the total force exerted below the flange. It is important to note that there is still a pressure difference between chamber A and chamber B. The force is equalized because the effective area above the flange is larger than the effective area below the flange. The difference in working area is such that the valve maintains at an open, balanced, position when the pressure in chamber B is approximately 86% of the pressure in chamber A.

As the temperature of the condensate approaches its boiling point, some of the control flow going to chamber B flashes into steam as it enters the low pressure area. Because the steam has a much greater volume than the water from which it is generated, pressure builds up in the space above the flange (chamber B). When the pressure in this space is 86% of the inlet pressure (chamber A), the force exerted on the top of the flange pushes the entire disk downward and closes the valve. With the valve closed, the only flow through the trap is past the flange and through the control orifice. When the temperature of the condensate entering the trap drops slightly, condensate enters chamber B without flashing into steam. Pressure in chamber B is thus reduced to the point where the valve opens and allows condensate to flow through the orifice in the valve seat. The cycle is repeated continuously.

With a normal condensate load, the valve opens and closes at frequent intervals, discharging a small amount of condensate at each opening. With a heavy condensate load, the valve remains open and allows a continuous discharge of condensate.

Orifice-Type Steam Trap

DOE facilities may use continuous-flow steam traps of the orifice type in some constant service steam systems, oil-heating steam systems, ventilation preheaters, and other systems or services in which condensate forms at a fairly constant rate. Orifice-type steam traps are not suitable for services in which the condensate formation is not continuous.

Although there are several variations of the orifice-type steam trap, each has one thing in common; it contains no moving parts. One or more restricted passageways or orifices allow condensate to trickle through, but do not allow steam to flow through. Some orifice-type steam traps have baffles in addition to orifices.

Summary

The following important information in this chapter is summarized below.

Steam Traps Summary

- A steam trap consists of a valve and a device or arrangement that causes the valve to open and close as necessary to drain the condensate from the lines without allowing the escape of steam. Steam traps are installed at low points in the system or machinery to be drained.
- The type of steam trap used depends primarily on its application. Types include ball float, bucket traps, thermostatic traps, bellows-type traps, impulse traps, and orifice-type traps.
- Impulse steam traps pass steam and condensate through a strainer before entering the trap. A circular baffle keeps the entering steam and condensate from impinging on the cylinder or on the disk. The impulse type of steam trap is dependent on the fact that hot water under pressure tends to flash into steam when the pressure is reduced.

FILTERS AND STRAINERS

When it is necessary to remove suspended solids from a liquid, the usual method is to filter or strain the liquid. The two methods differ only in the size of the mesh being used. Filtering removes the very small solids, and straining removes the larger solids. Because filtering and straining are for all practical purposes the same, this chapter will differentiate the two terms on the basis of application of the filter or strainer.

EO 1.16 DESCRIBE each of the following types of strainers and filters, including an example of typical use.

a. Cartridge filters
b. Precoated filters
c. Deep-bed filters
d. Bucket strainer
e. Duplex strainer

EO 1.17 EXPLAIN the application and operation of a strainer or filter backwash.

Introduction

Filtration is a process used to remove suspended solids from a solution. Other processes such as demineralization remove ions or dissolved ions. Different filters and strainers are used for different applications. In general, the filter passage must be small enough to catch the suspended solids but large enough that the system can operate at normal system pressures and flows. Filters and strainers are used throughout most DOE facilities. They are used in hydraulic systems, oil systems, cooling systems, liquid waste disposal, water purification, and reactor coolant systems.

Cartridge Filters

Figure 20 illustrates a typical multi-cartridge filter. The cartridges are cylinders and usually consist of a fiber yarn wound around a perforated metal core. The liquid being filtered is forced through the yarn, which is approximately 1/2 inch thick, and then through the perforations in the metal core to the filter outlet, which can be at either end. A cartridge filter may include several cartridges, the exact number depending on the liquid flow rate that must be handled.

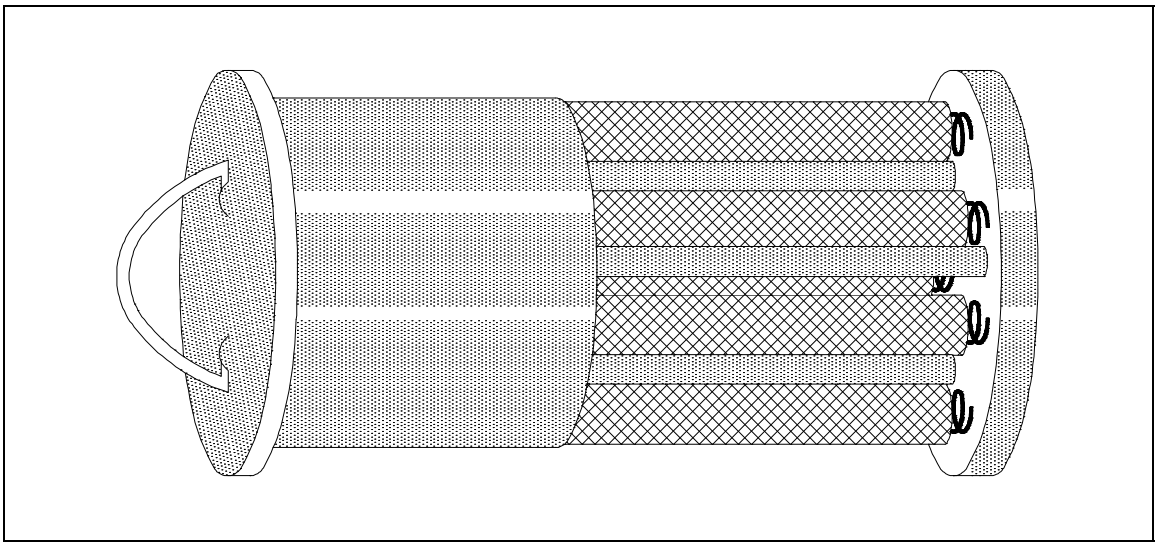

Figure 20 Typical Multi-Cartridge Filter

In the filter assembly illustrated in Figure 21, the cartridges are held between plates so that the water must pass through the layer of yarn to reach the filter outlet. The type of yarn that is used depends on the application. Some of the fibers commonly used include resin-impregnated wool or cellulose, cotton-viscose, polypropylene, nylon, and glass. In some applications that involve high temperatures or pressures, porous metal cartridges are used. These cartridges are usually made of 316 stainless steel, but inconel, monel, and nickel are also used.

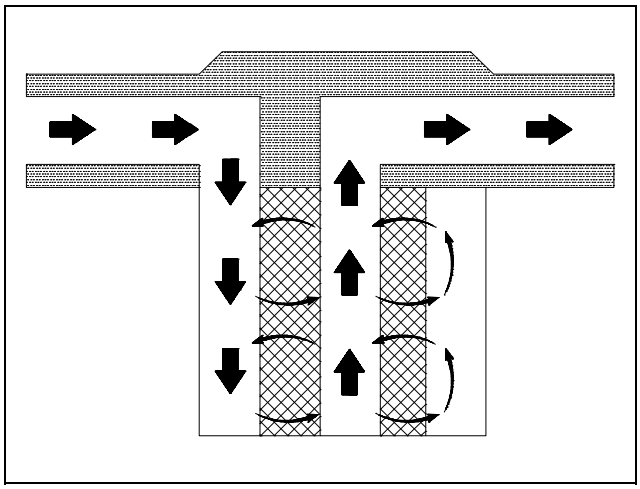

Figure 21 Cartridge Filter

Depending on the fiber or metal that is used, cartridges are available that will filter out all particle matter down to a specified size. For example, a certain cartridge might be designed to remove all particles larger than 10 microns, one micron, or even 0.1 micron. (A micron is 10^{-3} millimeters.)

Cartridge filters have the advantage of being relatively inexpensive to install and operate. Instruments measure the differential pressure across these filters to let the operator know when a filter is plugged and must be replaced. When the cartridges are removed from radioactive systems, the radiation levels can be very high. For this reason, the cartridges may be withdrawn into a shielded cask for moving to a storage area or a solid waste processing area. When the porous metal cartridges become plugged, they can be cleaned ultrasonically and reused. When this is done, the cleaning solution becomes contaminated and must be processed as liquid radioactive waste.

Another type of cartridge filter is the wafer, or disk filter. In this filter, disks are stacked to form a cartridge and placed down over a central perforated pipe. Each disk is typically 1/8 inch to 1/4 inch thick and made of cellulose or asbestos fibers.

Liquid that enters the disk filter moves up around the outside of the stack of disks, is forced between the disks, travels through the perforations in the central pipe, and then leaves the filter. The filtering action takes place as the liquid is forced between the disks.

As with the smaller cartridges, if a disk filter is used to filter radioactive water, it may be very radioactive when it is removed, and must be handled very carefully. One way to remove a disk filter is by means of a crane, which lifts the filter out of its housing and moves it to a shielded container. The disposal problem is one of the major disadvantages of cartridge and disk-cartridge filters.

Precoat Filters

A precoat filter eliminates the problem of physically handling radioactive materials, because the filter material (called the medium) can be installed and removed remotely. Inside the filter housing is a bundle of septums (vertical tubes, on which the filter medium is deposited). The septums in some filters are approximately 1 inch in diameter and 3 feet long and are usually made of perforated or porous metal (normally stainless steel). There may be several hundred of these septums in a filter. Septums in other filters are approximately 3 inches in diameter and 3 feet long and are made of porous stone or porous ceramic material. There are usually less than 100 of these larger septums in a filter.

The filtering medium fibers may be finely divided diatomite, perlite, asbestos, or cellulose. Diatomite, the least expensive medium, is used to filter liquid waste that will be discharged from the plant. Cellulose is generally used for processing water that will be returned to a reactor, because diatomite can allow silica leaching.

When a precoat filter is in use, water that enters the filter vessel passes through the filter medium that is deposited on the septums and then leaves through the outlet. Before the filter can be placed into operation, however, the filter medium must be installed; that is, the filter must be precoated.

The first step in precoating the filter is to close the inlet and outlet valves to the filter. The filter medium used is mixed with demineralized water in an external mixing tank to form a slurry, which is pumped through the filter. Some of the filter medium deposits on the septums and is held there by the pressure of water on the outside of the septums. At the beginning of the precoating process, some of the fibers of the filter medium pass through the septums, either because they are smaller than the openings or because they pass through lengthwise. Thus, there is still some filter medium in the water as it leaves the filter, so the slurry is recirculated again and again until the water is clear. Clear water indicates that all of the filter medium is deposited on the septums, and the filter is precoated.

One characteristic of the precoating process is that a very even layer of filter medium (approximately 1/8 inch thick) is deposited on the septums. This occurs because the circulating slurry follows the path of least resistance. When the coating at one point reaches a certain thickness, the slurry takes the fibers to another point, and this process continues until precoating is complete.

Because water pressure holds the filter in place, flow must be maintained through the recirculating loop to keep the medium from falling off. This is called a holding flow. As the inlet and outlet valves are opened for normal usage, called service flow, the holding flow is gradually cut off.

Backwashing Precoat Filters

After a filter has been precoated, it is put into service and kept on line until the pressure differential indicates that the filter medium is becoming plugged. When this occurs, the old filter medium is removed and the filter is precoated again. Filters are usually installed in pairs, so that one filter can remain in service while the other is undergoing the filter backwashing and precoating process.

Since water pressure helps to hold the filter medium against the septums, some of the old filter medium will fall off as soon as this pressure is removed. Backwashing is used to remove the filter medium that does not fall off. Backwashing is usually done in one of two ways. With some filters, demineralized water is pumped backwards through the center of the septums, and the filter medium coating is knocked off by the water as it comes out through the septums.

Most filters use a multi-step backwashing procedure. First, the inlet valve and the outlet valve are closed, and the drain valve and the top vent are opened to allow the water to drain. Then the drain valve and the vent are closed, and the inlet water valve is opened to raise the water level. The filter is equipped with a special high-domed top to trap and compress air. When the water inlet valve is closed and the drain valve is opened quickly, the compressed air forces water down through the center of the septums. This water knocks the filter medium off of the septums.

With both types of backwashing, the filter medium coating that is removed is sluiced out through a drain line to a filter sludge tank, where it is stored for further processing. The filter is then precoated again and put back into service.

With precoat filters, the type and quantity of filter medium is critical. If too little material or too coarse a material is used, some of the finely divided crud in the water may get into the openings of the septums. When the filter is backwashed, this crud is usually not removed. It continues to build up during subsequent use of the filter until the septums become so plugged that they have to be replaced.

If too much filter medium is used, the layer that builds up on the septums will bridge the area between the septums. When the filter is backwashed, these bridges are usually not removed. Therefore the bridging continues, and the filter runs become progressively shorter. Eventually, the filter must be opened and the filter medium must be removed manually.

Precoat filters are much more complicated than cartridge filters, and the equipment required is much more expensive to install and maintain. The major advantage of precoat filters is the remote operation, which eliminates the physical handling of highly radioactive filter cartridges.

Deep-Bed Filters

Deep-bed filters are usually found only in makeup water systems, where they are used to filter water after it has been treated in a clarifier. They are used to remove organic matter, chlorine, and very fine particulate matter.

A deep-bed filter is based on a support screen (decking), which is mounted a few inches above the bottom of the tank. The screen is perforated to allow water to flow through it. A coarse, aggregate layer of crushed rock or large lumps of charcoal is placed on top of the screen, and the deep bed itself (2 to 4 feet of granular anthracite or charcoal) is placed on top of the aggregate. The filter is sized so that there is 1 to 2 feet of "free board" above the deep bed.

When the filter is in service, raw water is pumped in through a pipe that feeds a distribution pipe above the deep bed. The water is filtered as it percolates down through the granules. (Charcoal granules will filter out organic matter, chlorine, and fine particulates, while anthracite granules remove only the particulates.) The water collects in the bottom of the tank, below the support screen, and leaves the filter through a pipe in the bottom of the filter vessel.

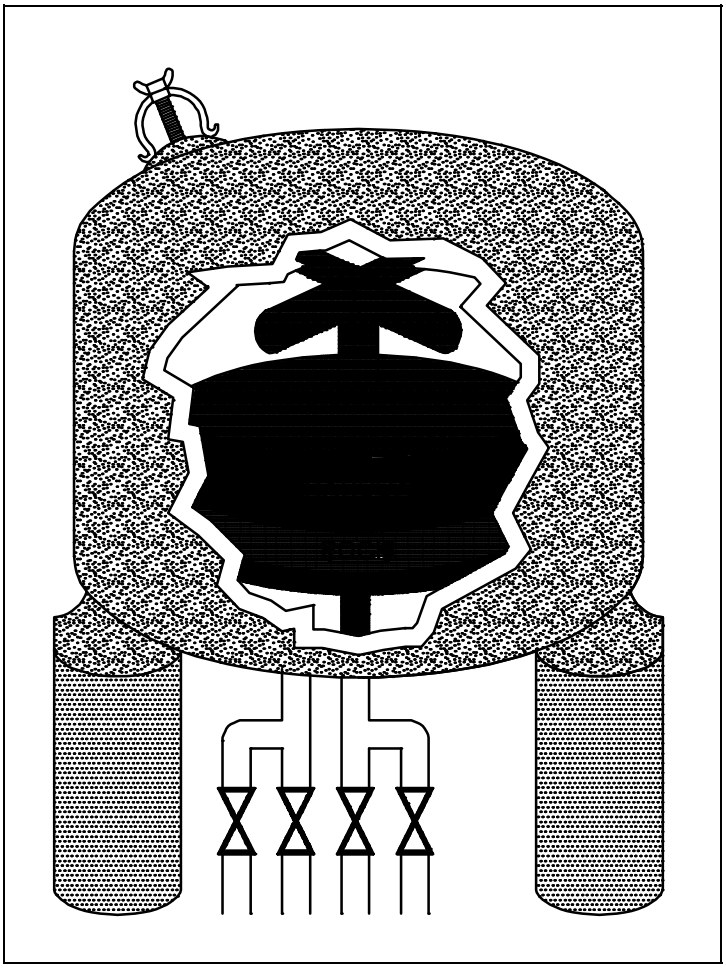

Figure 22 Deep-Bed Filter

Deep-bed filters, like precoat filters, are cleaned by backwashing. Water is pumped through the distribution piping near the top of the filter. The flow rate of the water is kept high enough to lift the granulated charcoal or anthracite up into the free space. The water washes away the deposits that have accumulated. When the backwash cycle is completed, the flow is stopped, and the granules settle back down into the filter bed. The filter can then be put back into service.

Metal-Edged Filters

Metal-edged filters are used in the lubrication (oil) systems of many auxiliary units. A metal-edged filter consists of a series of metal plates or disks. Turning a handle moves the plates or disks across each other in a manner that removes any particles that have collected on the metal surfaces. Some metal-edged type filters have magnets to aid in removing fine particles of magnetic materials.

Strainers

Strainers are fitted in many piping lines to prevent the passage of grit, scale, dirt, and other foreign matter, which could obstruct pump suction valves, throttle valves, or other machinery parts. One of the simplest and most common types of strainers found in piping systems is the Y-strainer, which is illustrated in Figure 23.

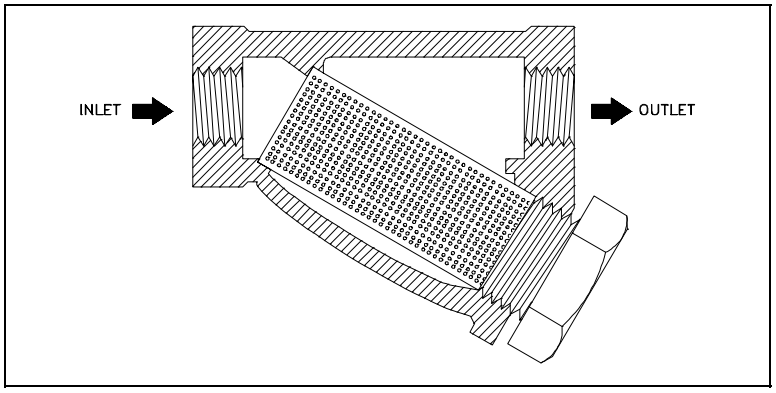

Figure 23 Y-strainer

Figure 24 illustrates three additional common types of strainers. Part A shows a typical sump pump suction bucket strainer located in the sump pump suction line between the suction manifold and the pump. Any debris that enters the piping is collected in the strainer basket. The basket can be removed for cleaning by loosening the strongback screws, removing the cover, and lifting the basket out by its handle.

Part B of Figure 24 shows a duplex oil strainer commonly used in fuel oil and lubricating oil lines, where it is essential to maintain an uninterrupted flow of oil. The flow may be diverted from one basket to the other, while one is being cleaned.

Part C of Figure 24 shows a manifold steam strainer. This type of strainer is desirable where space is limited, because it eliminates the use of separate strainers and their fittings. The cover is located so that the strainer basket can be removed for cleaning.

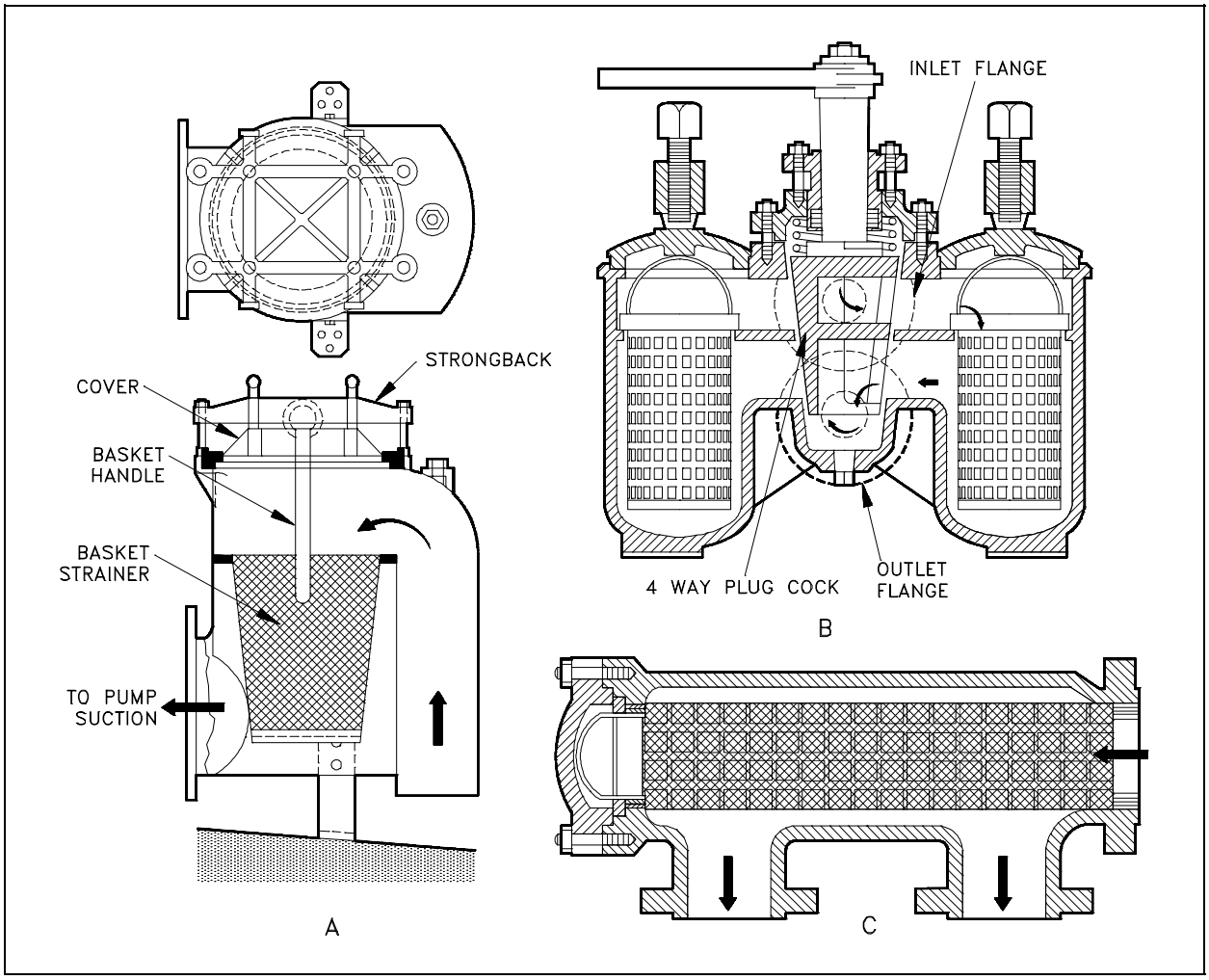

Figure 24 Common Strainers

Backwashing

If the filter or strainer cannot be easily removed for cleaning, the system design will usually include a flowpath for backwashing. The backwashing of precoated filters has already been explained because it is more complex than a typical backwash. The intent of a backwash is to flow liquid in the opposite direction of normal flow, creating a pressure that pushes the debris off the strainer or filter. The debris is flushed to a waste tank or drain.

Normally, to establish a backwash lineup, the flowpath upstream of the inlet to the strainer or filter is closed, the flow path downstream of the outlet is closed, and a drain flowpath is opened.

The flush source is then opened and the flow goes into the outlet of the strainer or filter, through the strainer or filter, and exits the inlet to the backwash drain or waste tank, carrying the debris with it.

Summary

The important information in this chapter is summarized below.

Filters and Strainers Summary

- A cartridge filter may be a single cartridge or multi-cartridge filter. The cartridges are cylinders that usually consist of a fiber yarn wound around a perforated metal core. The liquid being filtered is forced through the yarn and then through the perforations in the metal core to the filter outlet, which can be at either end. This type of filter is used to remove fine particles in any flow condition. Radioactive systems may use these because they are inexpensive and easy to replace.

- Precoat filters consists of a filter housing that contains a bundle of septums, (vertical tubes, on which the filter medium is deposited) usually made of perforated or porous metal (normally stainless steel), porous stone, or porous ceramic material. The filtering medium fibers may be finely divided diatomite, perlite, asbestos, or cellulose. Diatomite, the least expensive medium, is used to filter liquid waste that will be discharged from the plant. Cellulose is generally used for processing water that will be returned to the reactor, because diatomite can allow silica leaching.

- A deep-bed filter is based on a support screen (decking), which is mounted a few inches above the bottom of the tank. The screen is perforated to allow water to flow through it. A coarse, aggregate layer of crushed rock or large lumps of charcoal is placed on top of the screen, and the deep bed itself (2 to 4 feet of granular anthracite or charcoal) is placed on top of the aggregate. This type of filter is frequently used in raw water treatment.

- The bucket strainer is literally a bucket to catch debris. The bucket can be removed for cleaning by loosening the strongback screws, removing the cover, and lifting the bucket out by its handle. It is usually used in systems expected to have larger debris.

Filters and Strainers Summary (Cont.)

- A duplex strainer is a strainer consisting of two sides with a basket in each side. Only one side is placed in service at a time. These are commonly used in fuel oil and lubricating oil lines, where it is essential to maintain an uninterrupted flow of oil. The flow may be diverted from one basket to the other, while one is being cleaned.

- If the filter or strainer cannot be easily removed for cleaning, the system design will usually include a flowpath for backwashing. The intent of a backwash is to flow liquid in the opposite direction of normal flow, creating a pressure that pushes the debris off the strainer or filter. The debris is flushed to a waste tank or drain.

  Normally, to establish a backwash lineup, the flowpath upstream of the inlet to the strainer or filter is closed, the flow path down stream of the outlet is closed, and a drain flowpath is opened. The flush source is then opened and the flow goes into the outlet of the strainer or filter, through the strainer or filter, and exits the inlet to the backwash drain or waste tank, carrying the debris with it.

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CONCLUDING MATERIAL

Review activities:

DOE - ANL-W, BNL, EG&G Idaho, EG&G Mound, EG&G Rocky Flats, LLNL, LANL, MMES, ORAU, REECo, WHC, WINCO, WEMCO, and WSRC.

Preparing activity:

DOE - NE-73
Project Number 6910-0024